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VII.

NOTES ON MODERN BOILER SHOP PRACTICE.

By Passed Assistant Engineer Albert C. Engard, U. S. Navy.

[Read before the Philadelphia Branch of the Society, Chief Engineer L. W. Robinson, U. S. N., in the chair.]

I have thought that it might prove of interest, especially to those readers of our Journal who have not had the opportunity for daily observation, to submit a memorandum of some of the more important points in connection with the practical building of modern boilers with thick plates for high pressures. Indulgence is craved for any omissions which may have occurred in the haste with which these remarks have been prepared. As my duty in connecton with the inspection of the *Newark's* machinery at the works of Messrs. Wm. Cramp & Sons has caused me to pay special attention to that, these descriptions apply more particularly to the boilers for that vessel, but they show the practice of this firm with all double-end three or four-furnace boilers.

To one whose experience in boiler making was gained with boilers of small diameters for comparatively low pressures, the present methods seem almost new and very much more exact.

Plate edges are no longer sheared, nor rivet holes punched; flanging by hand has almost disappeared, to be replaced by that done by hydraulic machinery, and hand riveting is never resorted to except where the machine cannot be used. These changes are due to several causes: the material, which will not stand shearing and punching without serious injury; the increased thickness of plates, necessitated by larger diameters and increased pressures, which renders hand work inefficient and slow; and the reduced factor of safety, which renders first-class work in every particular an absolute necessity.

The plates, when received at the works, are carefully inspected before any work is done upon them, as it occasionally happens that some defect has escaped the inspector at the mill. Each plate is also weighed, measured, and its thickness gauged to see that it is fit in every way.

The next step for tubes, braces and all plates that are not to be flanged is "pickling," which has for its object the removal of the mill-scale. As is well known, this mill-scale is electro-negative to the metal on which it adheres, and with it forms a galvanic battery, causing, under the conditions of ordinary working, the serious corrosion of the metal. Its removal is, therefore, important. The pickling tank is made of pine planks, three or four inches thick, about sixteen feet long, eight feet wide, and eighteen inches deep inside. The pickling bath is a five per cent. solution of sulpuric acid, though hydrochloric acid is also used. The plates are laid in the bath flat, being kept up from the bottom and apart from each other by old nuts placed at the corners and at the middle of the sides. As many are put in the bath at once as can be covered by the pickle. The duration of the pickling process depends on circumstances, but is usually about six hours. With use, the strength of the pickle diminishes and requires renewal. Such a tank as above described requires about five hundred pounds of acid when the bath is first made, and, when in steady use, about fifty pounds are added each morning, or after two shifts of plates have been pickled.

After removal from the pickle, the plates are thoroughly scrubbed with stout corn or hickory brooms, while a strong

stream of fresh water is played upon them, and they are then immersed in a bath of lime water, to neutralize any acid that remains, after which they are again washed with clean water. If the plates are too large for immersion in the bath, the lime water is poured on them.

After this treatment they present for a short time a beautiful silvery appearance, during which any defect shows most plainly. The action of the oxygen and carbonic acid of the air soon causes ordinary rust to cover the surfaces, but this has no bad effect.

The shell plates for these large boilers are heavy (those for the *Newark* weighing about two tons), and appliances are necessary for handling them. An overhead rail and traveller with a differential pulley carries the plate by means of clamps and chain slings.

In case the plates are too long for the tank while not too wide, or are too wide while of suitable length, half the plate is pickled at a time, the whole process of washing and brushing being completed before pickling the other half. If the plate is altogether too large for the tank, a wooden ledge about two inches high is built around the edges, being made tight with stiff red lead putty. The pickle is then poured on the surface and allowed to stay the usual length of time. It is then run off and returned to the tank, and the plate washed and brushed, after which it is turned over and the other side treated in the same way.

While on the subject of pickling, I may say that the plates for the ship's hull are treated in the same general way, but the tank is of different proportions, so that they can be placed on edge. When removed from the pickle the plates are run between two revolving wire brushes while a stream of fresh water is played on them. The brushes are about five feet long, eighteen inches in diameter, and made of fine steel wire extending about three inches from the body. Four vertical shafts, with rubber wheels eight inches in diameter and seven inches wide, act as drivers. They and the brushes are adjustable, and the plates are run (on rollers) between the brushes and back again, a reverse motion for the driving rollers being fitted. These tanks and brushes are not

large enough for the boiler plates, or they would have been used, as it is considered better to have the plates on edge in the pickle so that the scale can fall off as it is loosened.

The shell plates having now been pickled and found free from all defects, are prepared for bending and riveting. The sheets are marked to the proper size and the rivet holes laid out along the edges that will be circumferential. These holes are drilled in both edges of the middle ring (of a three-ring boiler) and in the outer edges of the two end rings; in other words, the holes are drilled in the sheets that will overlap. In the inner edges of the end rings a few "tack holes" (for bolting the sheets together in subsequent operations) are drilled. The sheets are then planed to the proper size, the edges being beveled for caulking, and are taken to a "four-roll" bending machine, where they are rolled to the curve of the shell for about twelve or fifteen inches at the ends; from this they go to the large "three-roll" machine, where the entire sheet is bent to the proper curvature. The butt-straps have meanwhile been planed to size, bent to form, the rivet holes laid out and a few "tack holes" drilled.

The shell is now erected on the turn-table of the drilling machine, the separate courses and the butt-straps being held together by bolts through the tack holes. There are three drills at the turn-table which are independent of each other, but can work at the same time. The holes already drilled in the middle course of the shell serve as guides for the drills in this work.

Owing to the fact that the tack holes are originally drilled in each piece (sheet or butt-strap) separately they are liable to be somewhat unfair, necessitating reaming out and the use of a larger rivet. For this reason I believe the tack holes should be made smaller than the size intended for rivets, so that the unfairness will disappear when drilled on the turn-table. The rivet holes in the middle course (of a three-course boiler) for the screw stays securing the combustion chamber are drilled at this time. If the top of combustion chamber is supported by braces from the shell, the holes in the latter for this purpose are now drilled. The shank of the drills is fluted like a rose-bit, and thus leaves a slight countersink.

Before riveting, the bolts are taken out and the burr and rust around rivet holes carefully removed, so that the sheets may come "metal and metal."

The method above described is followed for all other plates which are not flanged.

The sheets for the boiler heads and the tube plates of the combustion chamber are flanged before any other work is done on them. They are, of course, minutely inspected first of all as they have to undergo the most trying work. At the works of the Messrs. Cramp, Tweddell's hydraulic flanger, made in England for the Morgan Engineering Company of Alliance, Ohio, who are agents in this country, is used. This consists essentially of a substantial vertical frame curving into a horizontal overhang and carrying three hydraulic pistons, two vertical and one horizontal. One of the former is a "presser-foot" for holding the sheet firmly on the former block; the second turns the flange, and the horizontal piston "squares" or straightens the flange after it is turned. The "former" is a heavy cast-iron block, about two feet across and a foot thick. It has curves of three radii and one straight side for turning straight flanges. The curves have radii about one inch less than that of the desired curve of the flange, to prevent the latter from gripping the block. The edges of the block are curved to give the proper radius to the inside of the flange, and about in the following proportions:

Radius of curve on block for sheets ½ inch thick or less, ¾ inch; for sheets from ½ to ¾ inch, ⅞ inch; for sheets from ¾ to 1 inch, 1 inch. The die on the second vertical piston for turning the flange is made concave opposite the curve on the block, and is also curved in a horizontal plane; one corner is made taper, so as to turn the flange gradually. On the bed of the flanger is a center bolt or pintle, around which the sheet is swung. If it is large enough, the hole for this pintle is made in the sheet itself; but, if not, a piece of scrap plate is bolted to the sheet and the hole made in the scrap.

The sheet to be flanged having been cut to the proper size, (the edge for caulking is not chipped till after flanging,) it is

heated to a bright cherry red, swung by the crane to the flanger, centered by the pintle, and the "presser-foot" run down. The flanging piston is let down, and turns from six to eighteen inches (horizontally) of the flange. The presser-foot is raised, the plate shifted, and the process repeated until from four to seven feet have been turned. The flanging piston is then run up out of the way, and the horizontal piston worked to straighten the part turned down. As soon as the red heat is gone and a blue heat would show, the plate is returned to the furnace and reheated. Scrupulous care is necessary in this respect, as the evil effects of working steel at a "blue heat" have been thoroughly shown and insisted upon. The length of flange that can be turned at each heat depends on the skill of the workmen and the convenience of the appliances, but rarely exceeds about eight feet.

The flanging of the furnaee openings in the boiler heads is also done on the hydraulic flanger, but different appliances are used. A female die is bolted firmly to the bed plate of the machine, and a male die is keyed to a flange bolted to the two vertical pistons. The dies and flanges are all of cast-iron. The hole in the sheet is cut of such a size as to leave the flange of proper width, depending on the thickness of the sheet. In the case of a $\frac{9}{16}$-inch sheet three inches was the width of flange. The plate is heated in a furnace with a circular fire, so that the entire flange shall be heated uniformly. The plate having been placed centrally over the female die, the male die is run down until the cast-iron flange back of it brings up on the sheet. The keys and bolts securing the male die are now removed, the pistons raised, several blocks of cast-iron placed between the male die and the piston, and the piston is again run down, shoving the male die clear through the sheet and dropping it into the pit below. This completes the flanging for this furnace, and the plate is returned to the heating furnace, while the die is lifted out of the pit and again keyed to the pistons in readiness for turning the next flange. In this work an allowance must be made for the contraction of the furnace mouth in cooling, and about $\frac{1}{8}$-inch per foot is usual, so that a three-foot furnace would require a male die 3 feet $\frac{3}{8}$-inch in diameter. There should also be a

slight clearance in the female die, about $\frac{3}{16}$-inch, when the flange has been turned, being considered enough.

In flanging the upper sheets of the head, owing to the large extent of curved flange and small size of sheet, it is found necessary to make allowance for the contraction in cooling. For this reason the chord of the arc is made about half an inch less than the required dimension. In cooling the greater part of the contraction occurs in the flange, and this causes the chord to elongate to the proper size.

After the flanging is completed, the plates are heated and straightened on the floor used for bending ship frames. They are then returned to the furnace, heated to a cherry red, and annealed by being placed on the floor and allowed to cool gradually in the open air.

After annealing, the plates are fitted together, corners of flanges drawn down by hand where laps come, and the edges of flanges chipped to the proper size and for caulking. Generally the plates come together very well, owing to the care taken, but when they do not, they are brought up by bolts and nuts. At the corners it is sometimes necessary to warm the plates by applying thick pieces of red hot iron, and then by setting up on the nuts and "coaxing" with a heavy hammer, the plates are brought "metal and metal."

The fitting having been completed, the separate sheets composing the heads are laid on the floor, adjusted to the proper circle for the shells, and a few "tack holes" are drilled. The rivet holes are laid out and drilled along both edges of the middle sheet, but those in the lower edge of top sheet and upper edge of bottom sheet are not drilled till the heads are in place, when those in the middle sheet serve as a guide for the drill. A few tack holes are laid out and drilled in the flanges to agree with those already in the shell, and, the heads having been bolted to the shell, the rivet holes are drilled through them all round.

The openings for man holes, stop-valves and longitudinal braces in top sheets, for tubes in the middle one, and for man holes and braces in the bottom one, are cut. The stiffening

rings around man holes and washers around braces are got out and fitted, and the rivet holes laid out and drilled. The stiffening rings are put on the outside of heads.

The tube holes in the tube sheets of combustion chamber are laid out and drilled, tack holes made in the sheets composing the combustion chamber, and the latter bolted together, after which the rivet holes are drilled.

After careful inspection, the furnaces are cut to the proper length, rivet holes drilled in the front end and in the upper flange at back end, and they are fitted to the combustion chamber. The rivet holes are then drilled in the sheets of combustion chamber where the furnaces join them.

The work of fitting the sheets and preparing them for riveting having been completed, the latter process begins. Tweddell's hydraulic riveter is used, made by the same firm that furnished the flanger. The pressure used is 1,500 lbs. per square inch. The plunger which closes the rivet exposes a diameter of $13\frac{1}{4}$ inches to this pressure, which gives a stress of about 90 tons on the rivet. The "squeezer" plunger, used for bringing the sheets together, is $8\frac{3}{4}$ inches in diameter, which gives it a pressure of about 40 tons.

The advantages of hydraulic riveting over both hand and steam work are so well known as to make their enumeration unnecessary. For these heavy plates and large rivets hand riveting is very slow, and it is almost impossible to make the rivet properly fill the hole. Wherever machine riveting can be it is used. As compared with steam riveting, the hydraulic is more gradual and fills the hole better, as steam riveting acts more like a blow and may upset the head before the hole is filled. On the thinner sheets, and where the machine cannot get, hand riveting is resorted to. In the *Newark's* boilers the sheets of combustion chamber, the furnaces, the joints of sections of heads, and of heads and shells, stiffening plates around man holes, washers around braces and crow-feet for braces, were riveted by hand.

I may say that, as the rivet holes in adjoining sheets are drilled in place, there is no excuse for the use of a drift pin, and the orders against its use are stringent. With many boiler makers,

however, to use the drift has become second nature, and they do it in every hole, whether unfair or not, if the inspector and foreman are not looking. Where the holes are unfair, they must be reamed out and a larger rivet used, and I believe that in these thick sheets the use of the drift has no effect either way. The new generation of boiler makers will probably get along without the drift pin, but the old one seems almost past reform.

The Bureau of Steam Engineering requires that where hand riveting is used the rivet holes should be coned and conical rivets be used. I believe also that all rivet holes should be slightly countersunk, enough anyhow to remove the sharp edge left by the drill which must exert a very deleterious influence on the rivet when the severe stresses due to variation of temperature come into play.

The joints in the shell are riveted by the machine, after which the boiler is laid on its side and the inside seams are all carefully caulked. Meanwhile the combustion chamber and furnaces have been riveted together, and the outside seams, which would be inaccessible after they are in place in the boiler, are caulked. They are erected in the position they will occupy in the boiler, and held by temporary bolts and braces. The angles under bottom of combustion chamber are now fitted and riveted.

The combustion chamber and furnaces are next put inside the shell. The bottom sheet of one head having been bolted in place the furnaces are brought into the flanges for them by long bolts. The other bottom head sheet is then fitted to the furnaces and shell in the same way. The other sheets of the heads are now put in place and bolted up, and the rivet holes not yet made—that is, in flanges for furnaces, in flanges of heads and in the top and bottom sheets of the heads where joining the middle sheet—are drilled. The remaining rivets are driven, and all seams, inside and outside, are caulked.

The holes for screw stays in the side sheets of the back connections are drilled to agree with those already in the shell, the threads are tapped in them, the stays screwed in and caulked where the thread leaves the sheets, and nuts screwed on without washers or grommets. If the top of combustion chamber is sup-

ported from the shell, the braces for that purpose are fitted and riveted.

The next operation is putting in the tubes. The holes in the boiler head are larger than those in the combustion chamber, to allow of the more ready removal of the tubes. The stay tubes are the first ones fitted. The taps for cutting the threads are on a rod, and so arranged as to cut those in the combustion chamber first. The cutting portions of the two taps are about two inches further apart than the tube sheets, so that the thread in the combustion chamber is finished before that in the head is begun. A plain thread follows the cutting portion of the tap, thus keeping the threads in the two sheets continuous. A plain part of the rod, of the same diameter as the hole, precedes the tap at the head end of the rod. After the stay tubes are screwed in they are expanded with a roller expander and beaded over at the combustion chamber end. (In boilers for the merchant service both ends are beaded.) The plain tubes are then put in place and expanded with the same kind of tool. In boilers built from its own designs the Bureau of Steam Engineering screws one end of the tube in tight (the thread being taper,) and expands the other, and requires cast-iron flanged ferrules to be fitted to the combustion chamber end of the stay tubes, and washers recessed into the tube-sheet or other approved protection for the plain tubes. Some protection is certainly necessary with forced draught to prevent the rapid wearing out of the tube ends.

The longitudinal braces above the tubes and around the lower man holes are of forged steel, and are upset on the ends for threading. A nut goes on each side of the sheet. The braces are put in place, and a stiff putty of red lead and cast-iron borings caulked in around them; this putty is also put under the nut on the inside of the head, and the nut is set up hard. For the joint on the outside, lampwick smeared with white lead, and large enough to fill the countersink, is put under the nut, and the latter is set up with a block and fall. The work remaining to fit the boiler for testing before putting in place in the ship is largely that done by machinists, and what has already been given practically covers the work of the boiler maker.

VIII.

BOILER SHOP AND PLANT AT THE UNION IRON WORKS, SAN FRANCISCO, CAL.

By Assistant Engineer W. Stuart Smith, U. S. Navy.

The boiler shop of the Union Iron Works is in a brick building 200 feet long and 154 feet wide, occupying 104 feet in width of the building, the remaining 50 feet being taken up by the blacksmith shop, each shop running the full length of the building. The flanging furnaces, punches, shears, rolls, etc., occupy a width of 50 feet, and are on the side of the building opposite the blacksmith shop, the central space, 54 feet in width, being used as the erecting shop. Along each side of this space there is a row of cast-iron pillars about 12 inches in diameter and 20 feet apart, which support the roof and carry on their tops rails for two traveling cranes, which move the entire length of the building.

One of these is a 60-ton crane with an hydraulic lift, the engine for working the gearing and pumps being driven by compressed air of about 60 pounds pressure. The other is a power crane, and its use is confined principally to handling the work in the pit containing the hydraulic riveters. In addition to the traveling cranes there are, in this central space, five 2½-ton hydraulic cranes, having about eight feet lift and swinging through an arc of 180°. They are secured to the pillars, and enable light work to be handled very quickly by one man and a boy.

For handling at the flange furnace, there are two 5-ton cranes on the side, having hydraulic lift and a swing of 180°. All these side cranes have hydraulic power for lifting only, and the work is run in and out and the crane swung by hand. In the center line of the space occupied by the furnaces, however, there are three standard radial 5-ton cranes, which have a swing through 360°, and in which all motions of hoisting, running in and out,

and swinging are done by hydraulic power; and the radial arms are of such a length that work can be handled at the fires, at all machines, and deposited within reach of the traveling cranes in the erecting shop.

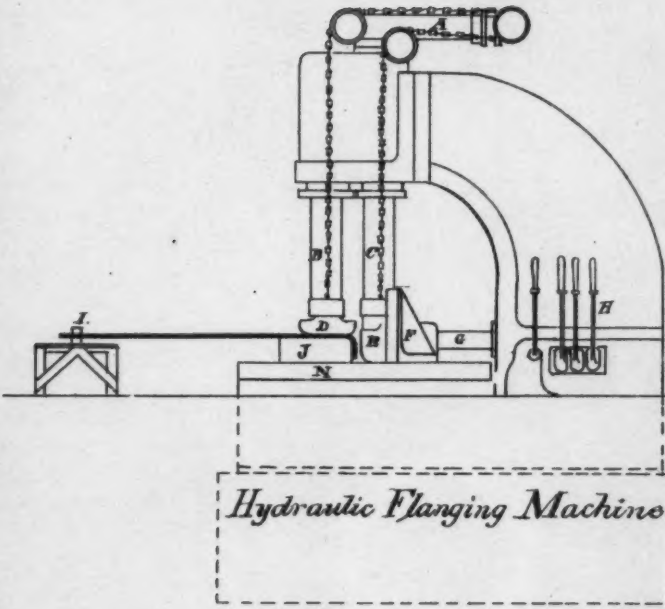
The following machines are in the shop: One automatic-feed power punch; two other power punches; three stationary and two portable hydraulic punches; two planing machines, in which the work is held by hydraulic power; two power shearing machines; four sets of rolls of different sizes; two radial drills, having a lift of about eighteen feet and a swing through 180°; three portable drills, with flexible shafting; one portable triple drill, with rope transmission, adjusted by a traveling weighted pulley; one large multiple machine for drilling tube sheets; three hydraulic riveters, and a hydraulic flanging machine.

For the power machines, one full line and two half lines of shafting run lengthwise the building. All the hydraulic machines are run with a pressure of 1,500 pounds per square inch, this pressure in the mains being produced by powerful pumps located in the machine shop.

A machine which has been erected within the last year, one which has proved exceedingly useful, is the hydraulic flanging machine. All plain flanging is done with this machine; boiler fronts are flanged for furnaces; manholes cut; fronts for furnace doors shaped, etc. A sketch of the machine is shown on Plate I, together with some formers which are in use in the shop, or which have recently been used. The latter were devised by Mr. P. Cronin, the foreman boiler maker.

As will be seen from the sketch, the machine consists of a strong cast-iron frame, to which are secured four hydraulic rams, *A*, *B*, *C* and *G*. Of these, *B*, *C* and *G* are used for flanging, and *A* for drawing back *B* and *C*. The machine, as shown, is arranged for flanging head sheets.

The female block has straight or curved faces, as required, and is represented at *J* bolted to the bed plate *N*. The plate is pivoted at *I* for boiler fronts or other curved sheets, and is held in place on the block by means of the head *D* secured to the ram *B*. The male former is shown at *E*, secured in the plunger



Hydraulic Flanging Machine

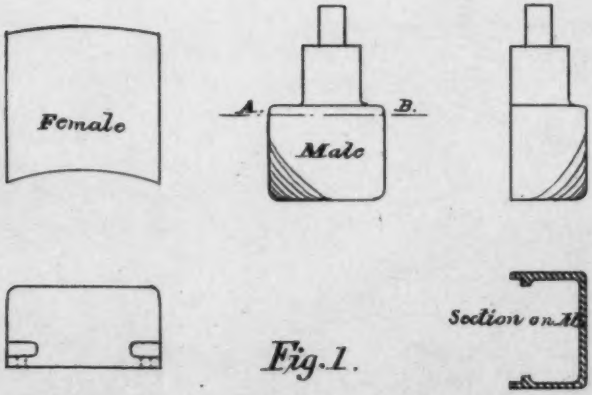
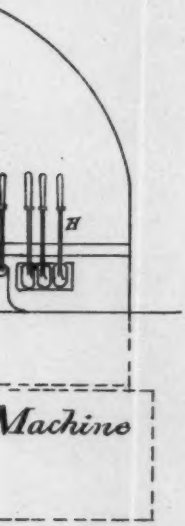
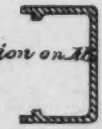


Fig. 1.

Formers for plain flanging.





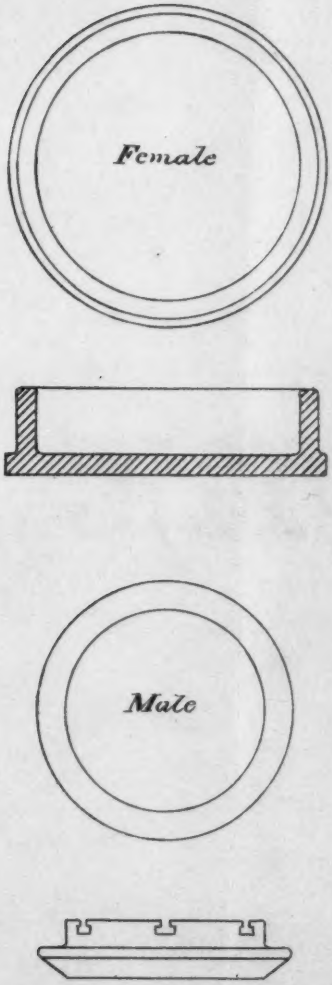


Fig 2.

Formers for flanging heads for furnace fronts

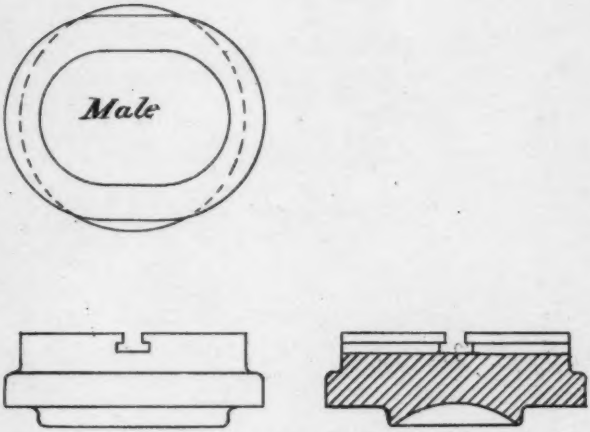
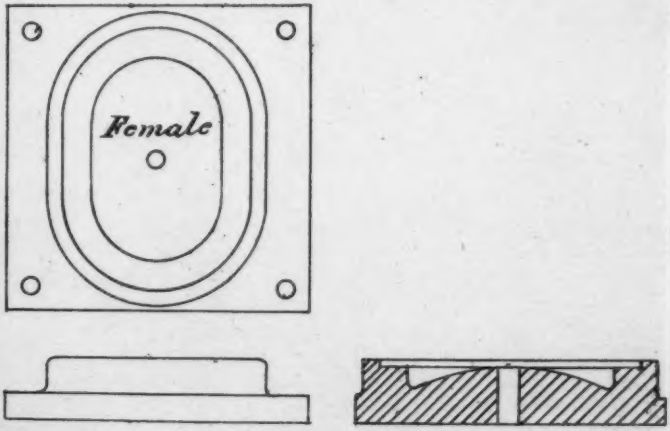
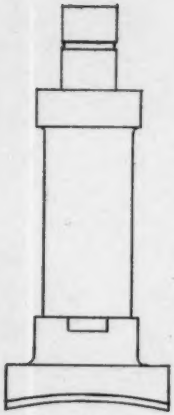
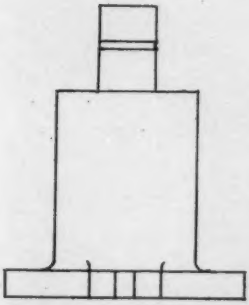


Fig. 3.

Formers for pressing out manhole plates







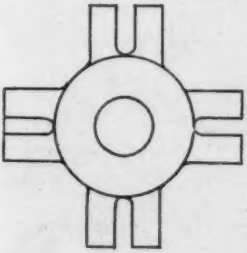
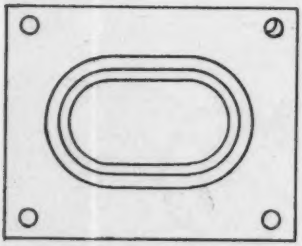


Fig. 5.

Cross-head block for securing male formers.



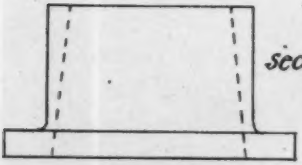


Fig. 4.

Stamp and die for cutting manholes.

C, and guided by *F*, which is also bolted to the bed plate *N*. After the plate has been bent over by the former *E*, the ram *C* is raised and the plate squared by the ram *G*.

For circular plates, the former *J* has its face curved, but a separate block need not be made for each radius, as a block may be used if its radius of curvature is not more than four inches greater or less than that of the plate to be flanged. For straight or convex flanging, the same male former may be used. About seven inches are bent down at one movement of the ram, and about four feet can be flanged at a heat.

Figure 2 represents the former used for flanging furnace fronts. As great power is required, the male die is secured to both rams *B* and *C*. In order to lessen the power required, the bending edge *K* is made so as to touch in but one circle.

Figure 3 represents the formers used for pressing out the 12x-16-inch manhole plates for the boilers of the *San Francisco*. Small formers like these are bolted to a head, as shown in Fig. 5.

For cutting manholes, stamps and dies, as shown in Fig. 4, are used. They are of cast-iron, the stamp being faced with steel at *A*, and the die having a steel ring, *B*. *A* is made concave, in order that a shearing action may take place, and the die is tapered, in order to allow it to clear itself freely.

All work such as manhole plates, furnace door fronts, etc., is formed by this machine, no hand work being done. In a pair of boilers recently constructed the manholes were flanged inside, and a bearing ring for the plate shrunk on the flange. In flanging large sheets, and in working around corners, it is necessary to finish up by hand, but the amount of hand work is very small.

The plungers *B* and *C* are 12¾ inches in diameter, and work with 1,500 pounds pressure per square inch. On one side of the machine there is an annular furnace for heating furnace mouths, and on the other a sector furnace for heating boiler front flanges, both located within the swing of a 5-ton hydraulic crane placed above the machine and used for handling the work.

There is at present in the shop two boilers 54 inches diameter and 16 feet long, each shell made of two sheets with longitudinal seams, but no transverse one. This is unusual for boilers

of this size. The dished heads for these boilers were formed at one heat.

The hydraulic riveters have dies for rivets from $\frac{5}{16}''$ to $1\frac{1}{4}''$. Two of these work by direct action of the rams, while the third is a "bull" machine, in which the ram acts on one arm of a bell crank, the die being set in the other arm. The direct acting machines have rams of 12 and 8 inches diameter.

When the shells of the *San Francisco's* boilers were being riveted it was found that there was a great tendency to set the boiler so that the dies did not come square with the surface of the boiler, with the result that the rivet head was driven over on one side. These rivets could be told at a glance by the shoulder which was produced by the die sliding over the head on account of the angularity. Close watch was kept, and, after a number had been cut out and the men found they had the work to do over again, greater care was exercised in placing the boiler, and the trouble avoided. Another difficulty that had to be contended with was the use of drift pins. All holes were drilled fair with the sheets in place, but when the heads were being riveted the heavy hammering (which was necessary in order to make the plates come together) stretched the plates so that at the end of a long line of rivets the holes would be found blind to a considerable extent. The men found it so much easier to true them up with a drift pin than to ream them out that considerable difficulty was experienced in preventing it, but after one gang of riveters had been discharged no draft pins were to be found.

A sketch is given of a machine used for welding the longitudinal seams of the *Charleston's* furnaces. This machine is the invention of Mr. Cronin, and is not patented. It consists of a cast-iron drum, in which are three openings, *a*, *a*, *a*, lined with fire-brick and having a blast entering the tuyeres through the pipe *d*. It is pivoted as shown, the furnace slipped on and the blast started. A piece of fire-brick is placed on the furnace over the fire as shown at M, to concentrate the heat. A welding heat is obtained in a few minutes, when the drum is turned within the furnace until the heated portion comes over the solid iron between the openings for the fires, and the joint is quickly

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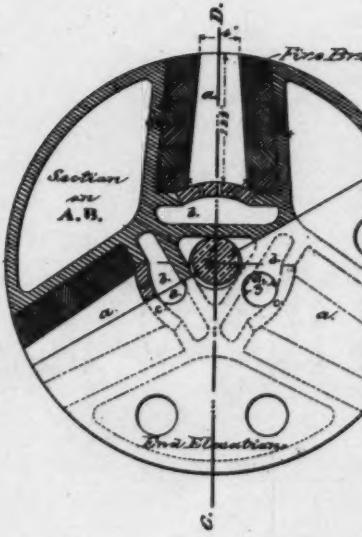


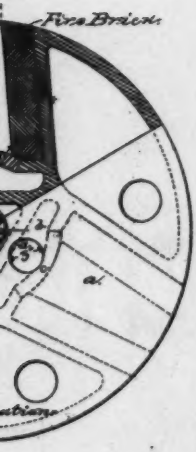
Cast Iron Drum

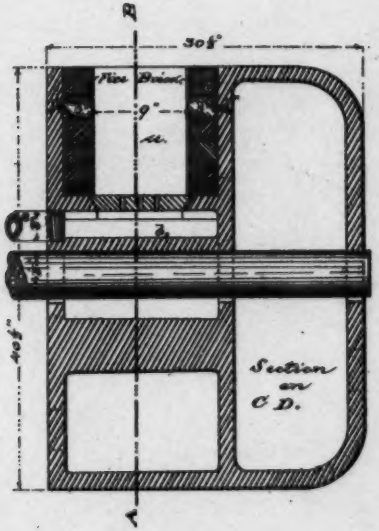
— for —

Welding Furna

In use at

Union Iron Work



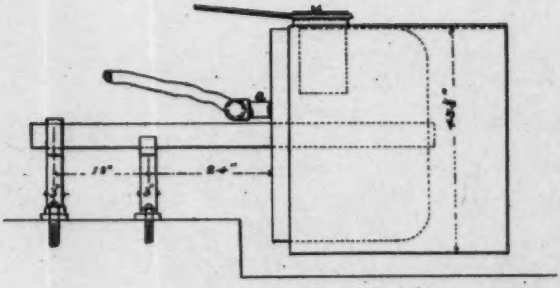


Scale ½" = 1 Ft.

Drum

Furnaces.

Works.



Scale ½" = 1 Ft.

welded. About five inches can be finished at a heat. Mr. Cronin found it necessary at first to give his personal attention to this machine, as the men were apt to overheat the plate and burn it; but they soon learned that too great a heat was not necessary, and experienced no further trouble. The machine was successfully used for welding the *Charleston's* furnaces, for which it was designed, but as Mr. Cronin thought electric welding would soon become general, he did not consider it worth while to take out a patent.

When drilling the shells of the *Charleston's* boilers, a simple and very effective method was devised for handling the boiler, and the same method was used for drilling the shells of the boilers of the *San Francisco.* The boiler was set in cradles on friction rollers, and a wire strap passed underneath it, the ends being carried to a drum secured to the swinging arm of the radial drill; on the shaft of the radial drill was a bevel gear which, by means of a lever, could be thrown into gear with a similar one on the axis of the drum; when the drum was thus made to revolve, the friction between the wire strap and the boiler was sufficient to cause the latter to revolve. One man was thus enabled to handle the whole boiler shell with perfect ease, and to adjust it to his drill with the greatest nicety.

IX.

NOTES ON THE EFFECT OF TEMPERATURE ON CERTAIN PROPERTIES OF VARIOUS METALS AND ALLOYS.

COMPILED BY ASSISTANT ENGINEER B. C. BRYAN, U. S. NAVY.

IRON AND STEEL.

Since the introduction of mild steel as a material for purposes of construction, attention has been called from time to time to certain curious phenomena attending its working at the building yards. Material, seemingly of good quality, will sometimes fail unexpectedly while being worked, or after being put into place in the structure. This has led to many investigations and experiments, and, although a localization of some chemical impurity such as phosphorus or carbon will sometimes be found, yet these investigations go to show that such failures are often caused by improper treatment of the material in working.

Experiments were made by Mr. J. F. Barnaby, in 1880 and 1882, at the Cyclops Works, Sheffield, the first set being to ascertain the temperature at which mild steel is liable to fail in working. A number of pieces of mild steel from seven different works were bent cold and hot, and in practically every case it was found that the steel would fracture when bent at a "blue heat."

Mr. Barnaby sums up as follows: "I am of the opinion that the heat which is most dangerous to work steel at is a temperature of about 540 F. I also consider this dangerous heat extends over a range of 150—namely, from 430 to 580 F.,—that is, from a light straw to a dark blue, although the danger may not be so great throughout the whole of the range as it is at the first named temperature; but still it is, in my opinion, extremely unsafe to put any work whatever upon mild steel within these limits, as it would be quite liable to sudden fracture."

A paper on "The Injurious Effects of a Blue Heat on Iron and Steel" was read by Mr. C. E. Stromeyer before the Institute of Civil Engineers, London, in January, 1886. (See Proceedings of Institute, vol. lxxxiv, or Navy Professional Papers, No. 21.)

From the results of a large number of experiments, Mr. Stromeyer concludes that working at a blue heat has the same influence upon iron as upon steel. His experiments were conducted principally upon bending specimens which were laid on the anvil of a steam hammer and bent 40°, then turned and bent 40° in the opposite direction (an anvil mold being used to hold the piece), and the number of bends was taken as the measure of the effect of the treatment on the material.

The following table shows the mean of some of the results of his experiments:

	Medium hard steel, $\frac{3}{8}$-inch.	Mild steel, $\frac{1}{8}$-inch.	Very mild steel, $\frac{3}{8}$-inch.	Lowmoor iron, $\frac{3}{16}$-in.
Unprepared or unannealed.....	21	$12\frac{1}{2}$	26	20
Broken hot (blue).....	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	3
1 preliminary hot bend.....	3 mean.	$2\frac{1}{2}$ mean.	11 mean.	12 mean.
2 preliminary hot bends.....	$\frac{1}{3}$ mean.	$\frac{1}{3}$ mean.	$\frac{3}{4}$ mean.	10 mean.
1 preliminary cold bend.....	20	$9\frac{1}{2}$	.....	.....
2 preliminary cold bends.....	$19\frac{1}{2}$	$8\frac{1}{2}$	19	13
4 preliminary cold bends.....	.....	.....	13	11
8 preliminary cold bends.....	.....	.....	15	2

Mr. Stromeyer says:

"All these results point unmistakably to the great danger which is incurred if iron or steel is worked at a blue heat. The difference between good iron and mild steel seems to be that iron breaks more easily than steel while being bent when either hot or cold; that iron suffers more permanent injury than steel by cold working, but that if it has successfully withstood bending when hot, there is little probability of its flying to pieces when cold, as is almost sure to be the case with mild steel. * * * All hammering or bending of iron and steel should be avoided unless the metals are either cold or red-hot. Where this is impossible, and where the plate or bar has not broken while blue-hot, it should be subsequently annealed."

Experiments were also made to determine the effect of local heating on steel. Several test pieces were made red-hot or blue-hot, and were then slowly cooled by holding one of their edges in cold water. As might have been expected, the medium hard steel lost much of its ductility. The other steel and the iron were not much affected, as will be seen from the following short table of the number of bends sustained by the samples:

	Medium hard steel.	Mild steel.	Very mild steel.	Lowmoor iron.
Unprepared or annealed.....	21	12½	26	20
Quenched red-hot in boiling water.....	24	10	....	.....
Quenched red-hot in cold water.....	1	10	19	20
Red-hot, quenched edge in cold water.....	3	8	25	27
Blue-hot, same.....	3	6½	19 and 19	21, 14

Mr. Stromeyer refers to one of the specimens that broke in a peculiar manner, as follows: "Before concluding it will be necessary to revert to the peculiar failure of one of the tensile test-specimens of the medium hard steel, which on straightening edgeways broke with a crystalline fracture. Of these pieces one was then bent in the anvil mold, but broke with a partly crystalline fracture at ½ bend instead of standing 21 bends." Inquiry showed that these pieces had been baked in a molder's core drying oven at a temperature of about a blue heat. In an article in *Engineering*, November 4, 1887, p. 491, Mr. Stromeyer again refers to these test pieces, and advances the opinion that sulphur in the fuel used in the drying oven caused its brittleness, and gives some later experiments made with the following results:

"Baking in a core-drying oven reduced the ductility of mild (35.7 tons) steel from an average of 22½ bends to 1½. A milder steel (28 tons) was reduced from 10 to 8½ bends. Baking in a kitchen stove reduced the ductility of very mild (23.4 tons) steel only from 26 to 22 bends, and Lowmoor iron (22.1 tons) from

20 to 16 bends. The above figures are the average number of bends through angles of 40° which the various samples withstood without breaking. The steel samples were $\frac{3}{8}$ inch thick, and the iron samples $\frac{3}{16}$ inch."

Mr. Stromeyer thinks that these experiments do not prove whether the steel was injured by the sulphurous gas from the fuel used or from heating to a blue heat. The U. S. Naval Advisory Board, in their report on mild steel, speak of the behavior of some quenching pieces as follows:

"The quenching pieces were at first heated in a smith's forge with cold blast, but subsequently in a small furnace attached to the annealing furnace and originally intended for annealing small pieces. A bridge 3 or 4 inches high between the fire and the hearth prevented the flame from playing on the pieces, and the furnace was never smoky except immediately after firing. The pieces were inserted as left curved by the shears. Lieutenant Gilmore reported a difference in the behavior of pieces under the quenching test according as they were heated in the annealing furnace or at the forge, in the latter case becoming hard to scratch with a file and at times highly tempered, brittle, and hard to work."

As these quenching pieces were heated to a cherry-red heat, which was far beyond the blue heat of the core-drying oven, it would seem that the theory advanced by Mr. Stromeyer, that the products of combustion from the fuel largely influenced the effect of heating on the character of the material, was the correct one. It would also seem from this that too much care cannot be exercised in the selection of fuel for fires in flanging or boiler shops.

The following series of tests were made at the Watertown Arsenal, and are copied from a paper "On the Physical Properties of Iron and Steel at Higher Temperatures," by James E. Howard, C. E. It is regretted that the diagrams referred to can not be included, but space forbids. They are to be found, together with much other valuable information, in "Notes on the Construction of Ordnance, No. 50," published by the Chief of Ordnance, U. S. Army:

TENSILE STRENGTH.

The tests were made upon the 1st series of steel bars, wrought-irons marked *A* and *B*, a muck-bar railway-axle, and cast-iron specimens from a slab of gun-iron.

The specimens were ″.789 diameter by 5 inches length of stem, having threaded ends 1″.25 diameter.

Wrought-iron *A* was selected because it had been found very hot-short at a welding temperature.

It had been strained with a tensile stress of 42,320 pounds per square inch seven years previous to being cut up into specimens for the hot tests.

The specimens, while under test, were confined within a sheet-iron muffle, through the ends of which passed auxiliary bars screwed to the specimens, the auxiliary bars being secured to the testing machine.

The heating was done by means of gas burners arranged below the specimen and within the muffle.

The temperature of the test-bar was estimated from the expansion of the metal, observed on a specimen length of six inches, using the co-efficients which were determined at lower temperatures, as hereinbefore stated, assuming there was a uniform rate of expansion.

Access to the specimen for the purpose of measuring the expansion was had through holes in the top of the muffle. The temperature was regulated by varying the number of gas burners in use, the pressure of the gas, and also by means of diaphragms placed within the muffle for diffusing the heat.

It is not thought that the instrumental error in measuring the length of the hot specimen exceeded ″.0002; which corresponds to a variation in temperature of $5\frac{4}{10}$ degrees, according to the lowest co-efficient of expansion used.

The duration of a test ranged from five to ten minutes, the longer time being employed with strong or with ductile specimens ruptured at lower temperatures.

The approximate elongations under different stresses were determined during the continuance of a test from measurements made on the hydraulic holders of the testing machine, at a convenient distance from the hot muffle, correcting these measurements from data obtained by simultaneous micrometer readings made on the specimen and the hydraulic holders at atmospheric temperatures.

While it does not seem expedient in one series of tests to obtain complete results upon the tensile properties at high tem-

peratures, yet, incidentally, much additional valuable information may be obtained while giving prominence to one or more features.

From these elongations the elastic limits were established where the elongations increased rapidly under equal increments of load. Proceeding with the test until the maximum stress was reached recorded as the tensile strength, observing the elongagation at the time, then, when practicable, noting the stress at the time of rupture.

The subjoined tables, VI to XIII inclusive, * * * exhibit representative results.

Table VI contains the results of tests made at atmospheric temperature; tables VII to XIII inclusive are results obtained at higher temperatures.

The elastic limits and tensile strengths are computed in pounds per square inch, both on original sectional areas of the specimens and on the minimum or reduced sections, as measured at the close of the hot tests.

If the contraction of area of the hot bar was small, these two sets of figures, showing the stresses on the cold bar, will therefore have nearer the same value than in case of large contraction.

From these results it appears that the tensile strength of the steel bars diminishes as the temperature increases from zero Fahr., until a minimum is reached between 200° and 300° Fahr.; the milder steels appearing to reach the place of minimum strength at lower temperatures than the higher carbon bars.

From the temperature of this first minimum strength the bars display greater tenacity with increase of temperature until the maximum is reached between the temperatures of about 400° to 650° Fahr.

The higher carbon steels reach the temperature of maximum strength abruptly, and retain the highest strength over a limited range of temperature. The mild steels retain the increased tenacity over a wider range of temperature.

From the temperature of maximum strength the tenacity diminishes rapidly with the high carbon bars, somewhat less so with the mild steels, until the highest temperatures are reached covered by these experiments.

The greatest loss observed in passing from 70° Fahr. to the temperature of first minimum strength occurred with steel 9–756, which was 6.5 per cent. at 295° Fahr.

The greatest gain over the strength of the metal at 70° was 25.8 per cent., shown by steel 1–833 at 460° Fahr.; although in total gain in pounds per square inch it was exceeded by steel 6–797 at 587° Fahr., where the gain was 15,120 pounds per square inch, or 12.8 per cent.

The several grades of metal approached each other in tenacity as the higher temperatures were reached. Thus, steels differing in tensile strength nearly 90,000 pounds per square inch at 70, when heated to 1,600 Fahr., appear to differ only about 10,000 pounds per square inch.

The elastic-limit appears to diminish with the increase of temperature.

Owing to a period of rapid yielding without increase of stress, or even under reduced stress, the elastic limit is well defined at moderate temperatures with most of the steels.

Mild steel shows this yielding point up to the vicinity of 500; in hard steels, if present, it appears at lower temperatures.

The gradual change in the rate of elongation at other times often leaves the definition of the elastic limit vague and doubtful, especially so at high temperatures. The exclusion of determinable sets would in most cases place the elastic-limit below the values herein given.

In approaching temperatures at which the tensile properties are almost eliminated, their exact determinations are correspondingly difficult, the tendency being to reach too high values.

ELONGATION UNDER STRESS.

Tables VI to XII inclusive show the elongations measured while the specimens were under the maximum loads, and after fracture.

The elongations at the time of reaching the maximum stress approximately represent the stretch of the metal independent of the local contraction of area at the place of rupture.

Inasmuch as the stress per square inch on the contracted section increases as the metal draws down, it is difficult to distinguish when general elongation ceases, and the stretch is confined to the section about to rupture, unless the entire length of specimen is accessible for inspection. Herein again there is

greater definitiveness of observation at moderate than at high temperatures.

Although the metal is capable of being worked under the hammer at high temperatures, it does not then possess sufficient strength within itself to develop much elongation, general elongation being greatest at lower temperatures.

This peculiarity is noticed: that greater rigidity exists under certain stresses at intermediate temperatures than at either higher or lower temperatures.

Thus it will be seen that specimen No. 1756, tested at 569° Fahr., showed less elongation under stresses above 50,000 pounds per square inch than the bars strained at higher or lower temperatures.

Also specimens Nos. 1888 and 1790, tested at 315° and 517° respectively, showed similar results, and other tests have confirmed the same.

This peculiar rigidity under certain high stresses seems to be found between the temperatures of about 300° and 700° Fahr.

Other remarkable features in the elongations are found in bars tested at temperatures of about 200° to 400° Fahr., in which there are displayed alternate periods of rigidity and relaxation under increasing stresses, resembling the yielding described as occurring with some bars, immediately after passing the elastic limit.

Specimen No. 1755, tested at 223° Fahr., illustrates the kind of behavior referred to.

The repetition of these intervals of rigidity and relaxation is suggestive of some remarkable change taking place within the metal in this zone of temperature, conspicuous in a series of tests possessing many remarkable features.

Observations made on the contractile force developed during cooling from higher temperatures showed the same kind of behavior then took place.

THE CONTRACTION OF AREA

at the place of rupture varies with the temperature of the bar.

It appears that the contraction of the mild and medium hard steels is somewhat less at 400° to 600° than at atmospheric temperatures, and within this range of temperature there is a tendency to fracture obliquely across the bar.

These characteristics are significant in so far as they harmonize with the brittleness frequently observed in bending tests at these temperatures.

The hard steels showed substantially the same contraction up to 500° Fahr. Above 500° or 600° the contraction increases with the temperature of the metal, with the exception of bars 8–750, 9–756, and 10–334, which showed a stage of diminished contraction at 1,100° to 1,200°, until at the highest temperatures some of the bars were drawn down almost to points.

A specimen of steel, 4–795, fractured at the temperature of 1,572°, contracted 98.9 per cent.

When these large contractions of area are displayed, the local contraction extends over a considerable length of specimen—necessarily concomitant features perhaps.

Center-punch marks on the surface of the specimens near the place of rupture have elongated in diameter upward of 300 per cent.

THE COLOR OF THE BARS AFTER COOLING

was not sensibly changed by temperature below 200°. After 300° the metal was light straw-colored; after 400°, deep straw; from 500° to 600°, purple bronze-colored and blue; after 700°, dark blue and blue-black.

After 800° some specimens still remained dark blue. After heating above about 800° the final color affords less satisfactory means of approximately judging of the temperature, the color remaining a blue-black, and darker when a thick magnetic oxide is formed.

A smooth glazed surface was found on specimens heated to 1,000° to 1,200°, which offered considerable resistance to the effect of acids and against corrosion in a damp atmosphere.

The oxide tints found at lower temperatures were immediately removed by the action of acids.

At about 1,000° the surface oxide reaches a tangible thickness, a heavy scale of .001-inch to .002-inch thickness forming as higher temperatures are reached. The red oxide appears at about 1,500°.

When the oxide has a tangible thickness it is more or less loosened from the surface of a ductile metal ruptured cold. Some specimens ruptured after exposure to the lower temperatures of 600° to 700° have had the surface color slightly broken, but such is not generally the case.

The fractures of specimens with straw-colored cylindrical surfaces were not colored.

Those with blue surfaces showed fractured ends deep straw and brown.

The fractures of dark blue and blue-black specimens agreed with the cylindrical surfaces.

The specimens were allowed to cool immediately upon their rupture, hence the surfaces of the fractured ends were exposed to the atmosphere only a brief period of time while at the maximum temperature.

IN THE TESTS OF RIVETED JOINTS

of steel boiler plates, at temperatures ranging from 70° to about 700° Fahr., the indications of the tensile tests of plain bars were corroborated.

Joints at 200° Fahr. showed less strength than when cold; at 250° and higher temperatures the strength exceeded the cold joints, and when overstrained at 400° and 500° there was found, upon completing the test cold, an increase in strength.

Opportunity was here offered to ascertain the effect of higher temperatures upon the shearing strength of wrought-iron rivets.

Rivets which sheared cold at 40,000 to 41,000 lbs. per square inch at 300° Fahr. sheared at 46,000 lbs. per square inch, and at 600° Fahr., the highest temperature at which the joints failed in this manner, the shearing strength was 42,130 lbs. per square inch.

The effect of higher temperatures upon the compressive resistance of the metal of the plates in front of the bearing surface of the rivets was not ascertained, as none of the joints failed from that cause, although high compressive stresses were reached.

TABLE VI.

TESTS OF COLD BARS. TEMPERATURE ABOUT 70° FAHR.

Test Number.	Marks.	Elastic Limit.		Tensile Strength.		Load at Rupture.		Elongation per cent.		Contraction of Area, per cent.	Appearance of Fracture.
		Total pounds.	Pounds per square inch.	Total pounds.	Pounds per square inch.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.		
1807	1–833	16,500	33,000	26,410	52,820	18,100	109,040	23.6	34.4	66.8	Silky.
1808	2–123	19,000	38,000	34,580	69,160	.....	.....	.....	26.2	41.6	Silky.
1809	3–782	23,000	46,000	40,990	81,980	35,300	129,300	.....	25.0	45.4	Silky, slightly granular.
1810	4–795	24,000	48,000	42,900	85,800	36,900	135,160	.....	24.0	45.4	Silky, trace of granulation.
1811	5–803	28,000	56,000	47,820	95,640	41,200	150,910	.....	22.0	45.4	Silky, trace of granulation.
1812	6–797	30,000	60,000	58,960	117,920	57,600	145,450	11.0	13.2	20.8	Granular.
1813	7–823	29,000	58,000	58,880	117,760	55,900	149,470	11.6	14.6	25.2	Granular.
1814	8–750	36,000	72,000	75,300	150,600	.....	.....	.....	7.6	8.0	Granular.
1815	9–756	40,500	81,000	77,300	154,600	.....	.....	.....	6.6	8.0	Granular.
1957	10–334	41,000	82,000	77,000	154,000	75,500	170,810	.....	8.6	11.6	Granular.
1912	Wrought-iron A.	22,500	45,000	30,590	61,180	28,400	83,040	7.6	9.8	31.6	Fibrous, trace of granulation.
1900	Wrought-iron B.	15,280	30,560	23,570	47,140	19,100	83,410	26.4	34.0	54.2	Fibrous.

TABLE VII.

O. H. STEEL BARS 1—833.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of Stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1770	0	35,000	106.1	27,680	55,360	104.8	19,500	117,470	21.6	34.2	66.8	Silky.	
1807	70	33,000	100.0	26,410	52,820	100.0	18,100	109,040	23.6	34.4	66.8	Silky.	
1859	195	32,200	97.6	25,680	51,360	97.2	18,500	102,210	21.0	27.0	63.8	Silky.	
1740	334	29,000	87.9	31,000	62,000	117.4	25,000	113,120	20.0	20.4	55.8	Silky.	
1860	460	25,800	78.2	33,220	66,440	125.8	24,900	108,730	15.8	25.6	54.2	Silky.	Straw.
1742	492	25,000	75.8	32,280	64,560	122.2	26,100	118,100	9.2	18.6	55.8	Silky, pale straw.	Straw.
1741	616	18,000	54.5	32,600	65,200	123.4	26,500	115,720	10.8	17.6	54.2	Silky, pale straw.	Purple and blue.
1735	731	23,000	69.7	27,080	54,160	102.5	16,000	88,400	16.2	.....	63.8	Silky, blue-black.	Blue-black, dark spots.
1739	845	17,000	51.5	28,620	57,240	108.4	18,800	103,870	19.0	29.0	63.8	Silky, dark blue.	Dark blue.
1861	934	16,000	48.5	21,400	42,800	81.0	11,600	92,060	27.4	45.6	74.8	Silky, blue-black.	Blue-black.
1738	1,021	6,000	18.2	9,600	19,200	36.4	.....	.....	6.6	26.2	90.9	Silky, blue-black.	Blue-black.
1737	1,045	8,000	24.2	12,500	25,000	47.3	.....	.....	10.0	28.6	86.8	Silky, dark blue.	Dark blue, dark spots.
1862	1,235	8,000	24.2	8,720	17,440	33.0	.....	.....	8.4	33.6	91.0	Silky, dark blue.	Dark blue, dark spots.

TABLE VIII.

O. H. STEEL BARS 3—78a.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture.		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of Stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1772	0	48,720	105.9	42,180	85,630	104.5	37,000	114,910	15.6	22.4	35.6	Granular.	
1809	70	46,000	100.0	40,990	81,980	100.0	35,300	129,300	.....	25.0	45.4	Silky, slightly granular.	
1755	223	42,000	91.3	39,400	78,800	96.1	34,000	128,790	13.4	20.0	47.2	Silky.	
1754	339	42,000	91.3	44,800	89,600	109.3	42,200	123,390	.....	14.0	31.6	Silky.	
1753	431	40,000	87.0	45,800	91,600	111.7	42,400	123,980	10.4	15.2	31.6	Silky.	Straw.
1756	569	33,000	71.7	47,700	95,400	116.4	38,500	136,040	16.2	24.4	43.4	Silky, indigo-blue.	Indigo-blue.
1869	651	26,000	56.5	43,600	87,200	106.4	30,200	136,650	12.2	24.2	55.8	Silky, dark blue.	Blue-black.
1759	738	26,000	56.5	42,250	84,500	103.1	30,600	133,620	13.8	23.6	54.2	Silky, blue.	Blue.
1757	832	24,000	52.2	41,800	83,600	102.0	30,000	131,000	14.2	24.2	54.2	Silky, blue-black.	Blue-black.
1758	960	19,000	41.3	35,100	70,200	85.6	22,600	106,600	9.0	15.6	57.6	Silky, dark blue.	Blue-black.
1871	1,021	20,000	43.5	28,060	56,120	68.5	15,800	87,290	10.4	26.8	63.8	Silky, dark blue.	Dark blue.
1760	1,106	18,000	39.1	27,200	54,400	66.4	15,700	80,100	8.1	14.6	60.8	Fine silky, blue-black.	Blue-bl'k and reddish br'n.
1872	1,198	12,000	26.1	18,500	37,000	45.1	8,300	62,880	15.8	31.0	73.6	Silky, dark blue.	Blue black.
1870	1,208	12,000	26.1	15,000	30,000	36.6	.....	.....	17.2	22.8	74.8	Silky, dark blue.	Dark blue.
1762	1,313	9,000	19.6	12,200	24,400	29.8	.....	.....	9.6	24.6	89.4	Silky, dark brown.	Dark brown.
1761	1,351	8,000	17.4	15,850	31,700	38.7	.....	.....	9.1	30.8	80.8	Silky, blue.	Blue, red spot.
1874	1,451	8,000	17.4	8,260	16,520	20.1	.....	.....	4.7	23.4	94.4	Fracture not completed.	Blue-black.
1873	1,620	4,000	8.7	5,680	11,360	13.9	.....	.....	7.9	36.0	95.4	Fracture not completed.	Blue-black.

TABLE IX.

O. H. STEEL BARS 6—797.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture.		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of Stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1775	5	62,000	103.3	60,560	121,120	102.7	58,600	143,980	12.0	13 6	18.6	Granular.	
1812	90	60,000	100.0	58,960	117,920	100.0	57,600	145,450	11.0	13.2	20.8	Granular.	
1789	214	57,000	95.0	55,920	111,840	94.8	53,800	148,210	11.0	13.4	27.4	Silky, trace of granular.	
1888	315	57,600	96.0	59,500	119,000	100.9	58,800	144,470	6.7	7.6	18.6	Granular, silky center.	Pale straw.
1890	342	57,200	95.3	59,200	118,400	100.4	.....	.....	.....	7.4	20.8	Silky, trace of granular.	
1793	422	51,000	85.0	64,120	128,240	108.7	63,800	152,270	7.6	8.0	16.2	Silky, straw color.	Straw.
1790	587	46,000	76.7	66,520	133,040	112.8	64,800	154,650	12.6	13.8	16.2	Silky, purple brown.	Brown and blue.
1794	676	51,000	85.0	60,600	121,200	102.8	50,200	155,900	9.6	16.4	35.6	Silky, dark blue.	Blue-black, greenish.
1885	801	46,000	76.7	52,920	105,840	89.8	40,600	139,040	6.9	13.4	41.6	Silky, dark blue.	Dark blue, checkered.
1792	953	43,000	71.7	45,400	90,800	77.0	39,200	148,480	7.4	15 6	47.2	Silky, blue-black.	Blue-black.
1886	1,078	34,000	56.7	33,670	67,340	57.1	18,600	81,220	5.0	17.6	54.2	Silky, blue-black.	Blue-black.
1887	1,274	20,000	33.3	19,520	39,040	33.1	.....	.....	4.0	15.0	72.2	Silky, blue-black.	Blue-black.
1791	1,603	.....	.....	10,500	21,000	17.9	.....	.....	4.0	23.8	91.6	Silky, dark blue.	Blue.

TABLE X.

O. H. STEEL BARS 10—334.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture.		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of Stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1957	70	82,000	100.0	77,000	154,000	100.0	75,500	170,810	.....	8.6	11.6	Granular.	
1971	70	80,000	.....	77,700	155,400	.....	76,300	172,620	.....	7.4	11.6	Granular.	
1960	265	76,000	92.7	73,980	147,960	96.1	73,300	165,840	7.9	7.4	11.6	Granular.	
1962	384	66,000	80.5	83,700	167,400	108.7	83,300	188,460	8.0	7.4	11.6	Granular.	Light straw.
1961	405	70,000	85.4	76,900	153,800	99.9	76,000	171,950	6.0	5.8	11.6	Granular.	Straw.
1959	505	82,000	100.0	84,320	168,640	109.5	83,800	189,590	9.4	10.0	11.6	Granular, brown.	Dark blue.
1958	656	62,000	75.6	74,980	149,960	97.4	61,000	172,800	7.7	13.8	29.4	Silky, dark blue, spongy.	Light purple and bronze.
1952	736	66,000	80.5	67,100	134,200	87.1	53,900	148,480	6.2	11.6	27.4	Spongy, dark blue.	Dark blue.
1972	867	52,000	61.4	59,500	119,000	77.3	52,800	141,180	5.3	8.6	25.2	Silky, dark blue.	Blue-black.
1953	908	56,000	68.2	55,000	110,000	71.4	42,800	117,910	4.8	15.2	27.4	Spongy, greenish blue.	Blue-black.
1954	1,116	40,000	48.8	39,400	78,800	51.2	32,000	76,370	4.3	11.6	16.2	Spongy, dark blue and purple.	Blue-black.
1951	1,384	18,000	22.0	20,600	41,200	53.5	15,500	43,910	3.5	7.6	29.4	Spongy, dark blue.	Dark blue.
1973	1,511	.....	.....	14,040	28,080	18.2	.....	.....	3.4	18.8	52.4	Dull, silky, blue-black.	Blue-black.
1955	1,638	.....	.....	9,300	18,600	12.1	.....	.....	3.3	23.8	57.6	Spongy, blue.	Blue.

TABLE XI.

WROUGHT-IRON A.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture.		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of Stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1912	70	45,000	100.0	30,590	61,180	100.0	28,400	83,040	7.6	9.8	31.6	Fibrous, trace of granulation.	
1920	308	52,000	115.6	33,200	66,400	108.5	.....	.....	4.6	8.2	20.8	Fibrous.	Straw.
1913	570	44,000	97.8	35,000	70,000	114.4	34,100	83,780	10.7	13.0	18.6	Fibrous, dark purple.	Straw and purple.
1915	689	46,000	102.2	31,000	62,000	101.3	.....	.....	9.5	12.8	20.8	Fibrous, dark blue.	Dark blue and bronze.
1916	889	36,000	80.0	26,000	52,000	84.9	23,700	61,560	8.2	15.8	23.0	Fibrous, blue-black.	Blue-black.
1917	991	24,000	53.3	18,580	37,160	60.7	15,700	45,910	6.0	19.0	31.6	Fibrous, blue-black.	Blue-black.
1914	1,164	14,000	31.1	10,420	20,840	34.1	10,200	31,680	5.8	19.4	35.6	Fibrous, blue-black.	Blue-black.
1918	1,322	9,000	20.0	7,270	14,540	23.8	.....	.....	2.5	18.4	41.6	Fibrous, blue-black.	Blue-black.
1919	1,568	.....	.....	3,180	6,420	10.5	.....	.....	1.8	12.0	32.9	Fibrous, blue-black, spongy.	Blue-black.

TABLE XII.

WROUGHT-IRON B.

Test Number.	Estimated Temperature, Degrees Fahr.	Elastic Limit.		Tensile Strength.			Load at Rupture.		Elongation, per cent.		Contraction of Area, per cent.	Appearance of Fracture when cooled.	Color of stem when cooled.
		Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Per cent. of cold bar.	Total pounds.	Pounds per square inch.	Under maximum load.	After rupture.			
1900	70	30,560	100.0	23,570	47,140	100.0	19,100	83,410	26.4	34.0	54.2	Fibrous.	
1911	179	28,400	92.9	23,600	47,200	100.1	.....	.....	20.8	24.6	47.2	Fibrous.	
1852	228	29,600	96.8	26,580	53,160	112.8	24,400	78,210	17.4	21.2	37.6	Fibrous.	
1850	256	28,000	91.6	24,800	49,600	105.2	22,800	84,160	11.7	17.6	41.6	Fibrous.	
1849	367	28,000	91.6	29,360	58,720	124.6	27,100	84,160	12.0	17.4	35.6	Fibrous.	Pale straw.
1851	476	14,000	45.8	29,580	59,160	125.5	26,100	83,650	14.4	21.6	37.6	Fibrous, bronze color.	Bronze.
1856	592	14,000	45.8	29,260	58,520	124.1	25,300	83,770	16.0	23.4	39.6	Fibrous, dark bronze.	Blue-black.
1854	684	14,000	45.8	28,070	56,140	119.1	24,100	77,240	16.2	24.8	37.6	Fibrous, deep blue.	Blue-black.
1853	874	12,000	39.3	20,180	40,360	85.6	12,500	56,560	10.9	30.8	55.8	Fibrous, blue-black.	Bronze-black.
1907	915	12,000	39.3	19,100	38,200	81.0	11,700	55,190	13.3	29.8	57.6	Fibrous, dark blue.	Dark blue.
1904	964	14,000	45.8	18,250	36,500	77.4	13,400	60,630	10.8	26.8	55.8	Fibrous, blue-black.	Blue-black.
1857	1,079	12,000	39.3	11,780	23,560	49.9	.....	.....	6.9	18.6	65.4	Fibrous, blue-black.	Blue-black.
1902	1,201	.....	.....	8,390	16,780	35.6	.....	.....	9.2	44.0	72.2	Fibrous, blue-black.	Blue-black.
1903	1,434	.....	.....	3,000	6,000	12.7	.....	.....	30.8	40.0	72.2	Fibrous, blue-black, spongy.	Blue-black.
1858	1,518	.....	.....	3,700	7,400	15.7	.....	.....	13.6	36.8	78.4	Fibrous, blue-black.	Blue-black.

TABLE XIII.

MUCK-BAR AXLE, NO. 6.

1825	195	26,800	.....	25,780	51,560	.....	23,700	81,160	13.6	17.2	41.6	Fibrous.	
1826	379	24,000	.....	32,300	64,600	.....	30,800	87,250	15.2	17.0	29.4	Fibrous.	Straw.
1824	565	16,000	.....	31,180	62,360	.....	29,200	80,440	17.8	20.8	27.4	Fibrous, dark purple.	Light blue.
1827	813	14,000	.....	21,790	43,580	.....	14,000	49,470	12.0	27.6	43.4	Fibrous, blue-black.	Blue-black.

ALLOYS.

The following table, taken from *Engineering*, October 4, 1889, p. 414, contains the results of some tests made by Professor W. C. Unwin, F. R. S.:

TESTING OF METALS AT DIFFERENT TEMPERATURES.

	Laboratory number.	Diam. in inches.	Area of section in square inches.	Temperature in degrees F.	Tenacity in pounds per square inch.	Elongation in two inches. Per cent.	Contraction of section. Per cent.
Yellow Brass.	938	.308	.07451	Atmosp'c	53,960	41.0	61.0
	941	.309	.07499	258	50,270	30.5	28.0
	939	.307	.07402	400	47,560	19.0	10.0
	940	.312	.07645	500	41,060	5.0	Very little.
	942	.308	.07402	602	35,520	2.5	"
	943	.309	.07499	640	32,450	1.0	"
Delta Metal. (Rolled.)	945	.249	.04870	Atmosp'c	69,800	20.0	55.0
	949	.243	.04638	260	63,400	22.0	47.0
	946	.249	.04870	400	59,540	25.0	53.0
	944	.249	.04870	500	53,380	27.9	59.0
	947	.245	.04714	570	43,280	38.5	60.0
	948	.240	.04524	650*	35,930	33.0	48.0
Muntz Metal.	950	.302	.07163	Atmosp'c	55,280	35.0	59.6
	951	.309	.07499	300	51,140	28.5	41.2
	952	.310	.07548	400	46,680	37.5	55.1
	953	.311	.07596	500	42,140	28.5	38.4
	954	.306	.07354	600	37,380	17.0	19.2
	955	.310	.07548	650	38,420	16.0	Very little.
Gun Metal.	977	.376	.11104	210	26,120	10.0	15.8
	980	.376	.11104	380	27,460	17.0	18.2
	979	.376	.11104	406	24,770	12.5	12.8
	957	.309	.07499	440	27,550	16.5	7.6
	981	.376	.11104	500	17,560	13.0	14.8
	978	.376	.11104	600	11,690	1.5	2.1
	982	.376	.11104	600	17,560	.....	Very little.
	960	.311	.07596	615	10,790	.....	"
Cast Brass.	989	.376	.11104	Atmosp'c	27,890	24.0	16.4
	991	.376	.11104	350	26,500	27.5	23.4
	992	.376	.11104	450	23,300	23.0	22.5
	990	.375	.11045	500	17,220	11.5	16.2
	993	.376	.11104	550	17,200	13.5	17.8
	994	.376	.11104	645	7,235	.....	Very little.
Phosphor Bronze. (Cast.)	995	.312	.07645	Atmosp'c	35,970	13.5	10.0
	1000	.312	.07645	270	31,720	12.5	12.4
	997	.312	.07645	350	27,460	7.5	10.0
	999	.312	.07645	430	27,800	10.5	8.7
	996	.312	.07645	500	24,860	6.0	6.3
	998	.312	.07645	600	18,300	3.5	2.5

*About.

In these experiments the bars to be tested were fixed in an oil bath heated by a gas jet. The middle part of the bar for a length of 2 inches was turned down to a diameter of $\frac{1}{4}$ or $\frac{5}{16}$ inch. The temperature was taken by a mercurial thermometer. It is believed that the temperatures are quite accurate, except those above 600°. Above 600° the thermometer behaved irregularly. The bars were broken in a small special testing machine of the manometer type, the pressure on the diaphragm being balanced by a mercurial column. Some of the gun metal bars first cast were unsound and were replaced by others, which partly accounts for the irregularity of the results in the tests of this metal.

OTHER METALS AND ALLOYS.

Engineering for October 25, 1889, contains the following:

"*Tensile Tests at Varying Temperatures.*—M. André Le Chatelier has recently made a number of experiments on the tensile strength of metals at varying temperatures. The specimens tested were annealed wires $\frac{1}{4}$-inch thick, which were heated in an air bath. The results obtained are given in the following table." The results are given in pounds per square inch of section:

	Temperatures—Fahrenheit.								
	59°	212°	302°	392°	482°	572°	662°	752°	860°
Copper	35,840	32,480	26,880	23,970	19,710	18,140	13,440	9,856	5,152
Aluminium	26,210	21,280	18,140	14,110	10,750	8,065	5,376	3,360	2,240
Nickel	78,400	78,400	78,400	78,160	76,610	72,360	62,500	52,420	43,230
Silver	24,420	22,620	19,260	16,130	12,540	10,080	8,512	7,392	6,720
Aluminium bronze	75,700	74,600	72,360	69,900	66,760	62,940	52,420	32,930	14,110
Copper, iron, nickel	60,250	60,030	58,910	57,800	55,780	52,420	39,650	25,980	11,200
Zinc	17,700	3,360	1,324	896	.....	896	.....	.....	.....

X.

TUBULOUS BOILERS.

By Assistant Engineer S. H. Leonard, U. S. Navy.

One of the most important questions arising in connection with marine machinery at the present time is that concerning the improvement of the steam generator. The Scotch boiler, now in universal use, leaves much to be desired even at present pressures, and if quadruple-expansion engines are soon to supersede the triple type, as now seems highly probable, steam of 225 to 250 pounds pressure per square inch must be supplied, necessitating a radical change in the general type of boiler from that now in use.

At the present time, with but few exceptions, quadruple-expansion engines are working at a pressure of 180 pounds only. This is accounted for by the fact that hitherto it has not been found possible to construct a marine boiler capable of withstanding pressures much exceeding 160 pounds without either considerably reducing the diameter or increasing the thickness of the shell plates. A reduction of diameter is obviously a backward step, while steel plates 1¼ to 1⅜ inches thick are about the maximum capable of being worked with satisfaction on the one hand, or for being used for the transmission of heat on the other.

In connection with the reduction of diameters, boilers of the locomotive type have frequently been tried, and some engineers are looking to this class of boiler as offering some advantage in regard to reduced weight, as well as in their adaptability to higher pressures. Their performances, however, up to the present time, have been far from satisfactory; many accidents have occurred on board the torpedo boats fitted with them, several of which were fatal; and serious leaks about tubes and seams develop after a short period of rapid steaming under forced draft.

In several cases where they have been fitted in battery, they proved costly failures, the cases of the English torpedo ram *Polyphemus* and the *Flavia Gioga* of the Italian navy being notable. Although the *Lepanto*, of the Italian navy, has recently been fitted with sixteen boilers of the locomotive type, in battery, and a favorable report made on their trial, little seems to have been proved thereby, as the conditions were far from severe. As the *Lepanto* is a ship of over 15,000 tons displacement, and the trials took place in smooth water, the boilers were perfectly steady, and consequently there was no uncovering of heating surfaces with the attending evils, so great in this type of boiler. The safety valves were loaded to the very moderate pressure of 60 pounds per square inch. The speed trials seem to have been of rather short duration, and yet after each forced draft trial the boilers had tubes leaking.

Many are looking to the type known as the water-tube or tubulous boiler for the solution of this question of higher pressures. This certainly has many advantages claiming attention, which may be itemized as follows:

Higher pressures.—One of the most important features of this type of boiler is its capability of working at any pressure which can be utilized by the steam engine, and at the same time the danger from explosion is greatly reduced.

Weight.—As the parts of the boiler are small, the scantlings may be light and the requisite factor of safety retained, while at the same time a more free transmission of heat from the fuel to the water is secured. The water in the tubulous boiler averages from 5 per cent. to 15 per cent. of the weight of the empty boiler, while in the Scotch type the average is from 60 to 65 per cent.

Rapidity of generating steam.—The large and effective heating surface, together with the small bulk of water, which has a rapid circulation, enables this type of boiler to generate steam very rapidly without injury thereto, which is always a great advantage, and especially so in naval vessels.

Facility in making repairs.—The parts being small and comparatively light, can readily be carried in duplicate and fitted, when necessary, with little expenditure of time or skill.

In speaking of the Thornycroft boiler, the Director of Naval Construction of the Danish Navy says: "The Thornycroft boilers in the torpedo boats ordered during the last two years, 1887 and 1888, have, up to this date, never given any trouble. The steam pressure can be raised in a few minutes to 100 pounds, yet it has never happened that leakage at any tube or joint has appeared. The boiler is not liable to priming, and the water surface is not disturbed or *the heating surface uncovered* by the rolling of the boat. The combined weight of the boiler proper with its contents of water is considerably less than is the case with the locomotive boiler. Having a large and effective heating surface, the boiler is very economical as to coal consumption. * * We are, in fact, so satisfied of their superiority over the locomotive boiler, that without hesitation we fit these boilers in all new boats, and when locomotive boilers in older boats have to be taken out for repairs, we replace them with the tubulous boiler, as now done in the *Delfinen*."

In regard to the Thornycroft boilers built for torpedo boats for the government of India, the following results were obtained by Prof. Kennedy, of University College, in an experiment to determine their evaporative efficiency made in the fall of 1888:

Air pressure in inches of water.	I. H. P.	Lbs. of water per lb. of coal.	Lbs. of coal* per I. H. P.	Temperature of chimney.
0.00	89	13.4	2.28	421°
0.27	282	12.48	1.98	——
0.49	449	12.00	1.99	——
2.00	773	10.29	2.26	777°

*I. H. P. of main engines only used in this calculation.

The evaporative value of the coal was found by calculation, from its chemical constituents, to be equal to 15.4 pounds of

water per pound of coal from and at 212°. The efficiency of the boiler with natural draft was, therefore, $\frac{13.4}{15.4} = 87$ per cent. of the theoretical evaporation, a result concerning which Prof. Kennedy says: "This is the highest boiler efficiency I have ever found upon any trial with which I have had to do, if indeed it is not the highest on record in any trustworthy manner." Prof. Kennedy also says: "That one and the same boiler should be able to supply steam for powers varying from 90 to 770 I. H. P., maintaining so high an average efficiency throughout the whole range, is a most remarkable result. The weight of the boiler experimented on, with all its fittings, donkey, spare gear and funnel, was only 11.3 tons, which gives 68 I. H. P. per ton of boiler, and compares favorably with the locomotive boiler of about the same power in a torpedo boat which only gives 48 I. H. P. per ton, or the same type of boiler in use in the later English torpedo-catchers, which is still worse, only giving 43 I. H. P. per ton. These facts speak for themselves as to the advantage to be derived from the use of this type of boiler in the latter class of vessels. Proposals have been submitted by the English and several other governments for this type of boiler for powers varying from 3,200 to 6,300 I. H. P."

The principal requisites of a tubulous boiler are:

1st. *A free and natural circulation.* The serious lack of this property in the earlier water-tube boilers built from 1870 to 1875, and fitted in the *Montana*, *Propontis*, *Birkenhead*, *Meridith*, *Marc Antony* and other ships, was the primary cause of their disastrous failures. Circulation, in order to be natural, should be a systematic motion of the water from the upper to the lower part of the generator, and thence again to the surface, the steam when formed having a free and direct flow to the steam chamber or drum, and there being an equally free and direct flow for the water displacing it. In the later successful water-tube boilers every means is taken to facilitate this cycle of operations. Downcast pipes are provided to effectually prevent any confusion or want of order in the general circulation, and, as the flow in these pipes is always to be in one direction, downward, they should be so placed as to be free from any causes, however slight, tending to produce an op-

posite flow. In the older forms of boiler the circulation depended upon slight variations of density of the water in its different parts, and, although its motion might be energetic during rapid ebullition, it was without system or order; each drop of water was struggling to get somewhere or anywhere, and continually in conflict with its neighbor.

This is practically the circulation going on in the ordinary Scotch boiler, and is very different from the systematic rotation taking place in a well designed tubulous boiler.

2d. *A positive feed supply.*—In this class of boiler, with such a small water capacity, where the feed must be continuous and yet variable in amount, some kind of automatic device becomes necessary to assist those in charge, and especially is this a matter of concern when they are worked in battery.

3d. *Pure water.*—The necessity for pure water is certainly as great as, if not greater than, with other types of marine boilers. It is said that the tubes and other heating surfaces of the tubulous boiler are subject to rapid pitting and corrosion. It will probably be remembered that all forms of marine boiler were subject to the same failing in the early days of surface condensation, and indeed until means were adopted to check or arrest it. Such means seem to have been wholly or in part neglected in many of the water-tube boilers, with a result which might have been expected. If the same means and care are adopted in each case there would seem to be no good reason why one boiler more than the other should be subjected to this action.

4th. *Care.*—The life of a tubulous boiler will certainly be short without intelligent and systematic care. If builders would bear this fact in mind, and use their ingenuity in making all parts of their inventions more easily *accessible for frequent cleaning*, as well as for occasional repairs, much would be accomplished towards prolonging the life of the boiler.

The writer's experience, extending through the lives of three of the Herreshoff coil-boilers (square), may not be entirely devoid of interest. The boilers referred to contained in one case 4 square feet of grate and 55 square feet of heating surface; in the other two cases, 6¼ square feet of grate area and about 88

square feet of heating surface. In this type of boiler, with the relative positions of water and steam, the former in the top of the coil and the latter at the bottom, a forced or positive circulation is necessary, which is attained by means of a feed and a circulating pump worked from the engine cross-head. Provided these pumps ($\frac{7}{16}$-inch diameter of plunger) were thoroughly reliable, the circulation was all that could be desired. From the moment of the feed water entering the upper coil, until its exit as steam or water at the separator, every portion of it was taking the same course for a single point of exit; no dead water; no conflicting currents or confusion of any kind. The feed and circulating pumps, however, were not always reliable (due to several causes, which were not entirely preventable under the circumstances), and consequently required great care and attention. The circulating pump, working with water at a temperature due to the boiler pressure, was a source of considerable trouble, not giving unmistakable warning when it stopped, thereby inviting disaster or damage to the coil by overheating.

In each case these boilers lasted but two years, which may appear a short life for a boiler. All the conditions surrounding them, however, were conducive to a rapid detorioration. They were fitted in a 26-foot launch engaged in the Coast Survey Service. During about nine months in the year the launch left the ship every pleasant morning at 7 A. M., and was absent all day running lines of soundings until 5 P. M., and often later; there was no canopy to protect the boiler from rain, and, in rough weather, frequently the boiler was thoroughly drenched with salt water. Its almost constant use prevented the cleaning and care it could have otherwise received.

Distilled water was used over and over, with no means of counteracting its evil effects, such as suspending zincs in the boiler or filtering the feed water, and as a result the boiler's life was greatly shortened by "pitting."

In one of these boilers there were two cases where a leak the size of a pin head started in a return bend, and yet so little corroded was the iron all around these holes, that they were drilled, tapped and plugged; these plugs, $\frac{3}{16}$-inch diameter, holding until

the coil was condemned. The pitting seems to have been very regular in this respect, that after the first leak or break developed others followed at short intervals. In each of the boilers, after about twenty-two months' service, no less than ten or twelve breaks would develop in a month's time, rendering the launch decidedly unreliable. In every case pitting was the cause, and a somewhat singular thing in regard to these breaks, in one boiler especially, was that all but one took place in the third coil from the top. The boiler was composed of five coils or layers, the upper three being ¾-inch in diameter, and the two lower 1 inch. The upper coil, filled with water, and the lower coil, next the fire, filled with steam, showed little or no pitting. The water from the circulating pump entered the third coil, and it was here that steam and water were mixed (thus, in one sense, serving as the water level), and thence passing through the lower coils to the separator. In each case, upon final removal of the coils, the two nearest the fire were in much better condition than the others. The two upper coils had suffered materially from external corrosion, and seemed to have lost much of their life, being much more easily bent or crushed than ordinary pipe of the same thickness. This may have been due to the action of the soot, which accumulated rapidly upon their surfaces, and which was frequently damp or wet from rain or salt spray.

Although there are about 135 screw pipe joints exposed to the fire in each boiler of this type, I have yet to see the first one leak. The Herreshoff drop-elbows with ground joints, locked by a fine-threaded bolt, never leaked unless after having been broken several times to repair the coils; and this leakage only occurred in one or two instances after long wear and the joints had been somewhat burred. On the other hand, when necessary to take out a length of pipe for repairs, never have I been successful in unscrewing it from its return bend (or elbow, as the case might be), provided that it had been subjected to the heat of the furnace for any length of time. It was always necessary to cut it, and then dig the pieces or ends out of the fittings for the reception of new lengths, which, when fitted, were made up with black lead, instead of red lead and oil, and these have been

removed without cutting. Whether equal success would have been attained where there had been a longer exposure to the furnace heat, I am unable to say. In most cases with the drop-elbows, the bolts locking same were removed without twisting off the head, although this happened in one or two instances. These bolts also suffered from pitting.

Soot rapidly collects on these coils, especially so where soft coal is used, necessitating frequent cleaning to maintain their high efficiency. All manner of experiments were tried to rid the coil of this soot, but none proved so efficacious as a short length of steam hose with a jet to play between the coils soon after hauling the fire. Moreover, this method is free from the objection of many in damage to the coil or casing. To thoroughly clean the coil it was necessary to remove it from the boiler casing. This might be avoided by making the upper portion of the casing in detachable sections, and thus the breaking of so many connections, and more or less injury to coil and casing at each removal, would be unnecessary.

Because the tubulous boiler is composed of many elements, any one of which may be easily repaired or replaced, is no excuse for trying to prolong its allotted existence, which would simply result in continual annoyance and anxiety from frequent "break-downs." As a consequence, it would seem useless to carry any greater relative proportion of duplicate parts for this type of boiler than for any other.

In each of these boilers the top of the casing and smoke-pipe wore out much before the other parts, and when to be used with forced draught special care should be used to make these parts very substantial.

A generous ash-pit should be provided, if the annoyance of poor draft and melting grate-bars is to be avoided.

When the feed-water tank is situated under the boiler, unless well protected, the water will become quite hot, rendering an injector useless, and in some cases even the small auxiliary pump may become unreliable.

BOILERS.

Type.	Dimensions.	Grate Area.	Heating surface.	Ratio.	Comb'n.	Evaporation from and at 212° F.				Pr. cent. moist're	Weights.					Air pressure ins. of water.	Steam pressure lbs.	Coal.
					Per sq. ft. grate.	Per lb. coal.	Per lb. com'ble	Per sq. ft. H. surface	Per cu. ft. space		Empty. lbs.	Steam'g level.	Per I. H. P.	Per sq. ft. H. surface	Per lb. water evap'd.			
Belleville.	Length, 8′-6″ Width, 7 -0 Height, 11 -0 Space, 654.5 cu. ft.	34.17	804	1 to 23.5	12.8	9.6	10.42	5.2	6.4	6.31	40,670	42,770	204	53.2	10.1	Nat'l.	111	Bitm's.
Herreshoff.	Length, 4′-9″ Width, 3 -8 Height, 4 -0 Space, 69.6 cu. ft.	9	205.3	1 to 22	9.3 25.8	7.6 7.14	10.23 8.68	3.1 8	9.1 23.8	3.5 ...	2,945	3,050	96 36	14.8	4.8 1.8	Jet. Jet.	120 195	Anth. do.
Towne.	Length, 2′-6″ Width, 2 -6 Height, 3 -3 Space, 20.3 cu. ft.	4.25	75	1 to 17.6	4.3 24.5	10.46 5.6	13.4 6.77	2.7 8.2	10 30.4	...	1,380	1,640	172 56	21.8	8.1 2.6	Nat'l. 1.14	148 152	Anth. do.
Ward.	Diameter, 3′-2″ do. Drum, 1 -7 Height, 7 -2 Space, 42.7 cu. ft.	3.68	145.8	1 to 39.5	7.9 15.5 62.5	8.59 8.28 6.34	10.77 10.01 7.01	1.7 3.2 10	5.8 11 34.2	...	1,682	1,930	154 82 26	13.2	7.7 4.07 1.3	Nat'l. Jet. Jet.	0 17 161	Anth. do. Bitm's.
Scotch.	Diameter, 9′-0″ Length, 9 -0 Space, 572.5 cu. ft.	31.16	727.2	1 to 23.3	24.8 38	8.13 7.87	9.93 9.06	8.6 12.8	11 16.3	3.44 4.29	18,900	30,000	120 80	41.2	4.7 3.1	2.08 4.01	77 78	Anth. do.
Locomotive torpedo.	Length, 16′-8″ Width, 6′-4″ Height, 7′-6″ Space, 630.3 cu. ft.	28	1,116	1 to 39.8	98.3 120.8	6.97 6.62	...	17.1 20.05	30.5 36.2	...	...	34,990	47.7 33.3	31.3	1.8 1.2	3.13 4.95	125 123	Bitm's. do.
Ward.	Diameter, 10′-3″ do. Drum, 4 -6 Height, 11 -8 Space, 729.3 cu. ft.	53 66.5	2,473.5 2,490	1 to 46.6 1 to 37.4	55.04	8.03	8.44	9.47	32.1	11.6	26,533	30,474	26	12.3	1.3	2	160	Bitm's.
Thornycroft. (U. S. S. *Cushing*.)	Length, *10′-0″ Width, *4′-0″ Height, *8′-0″ Space, *560 cu. ft.	38.3	2,375	1 to 62	45	...	...	...	...	...	20,160	24,640	*31	10.3	...	3	245	Bitm's.

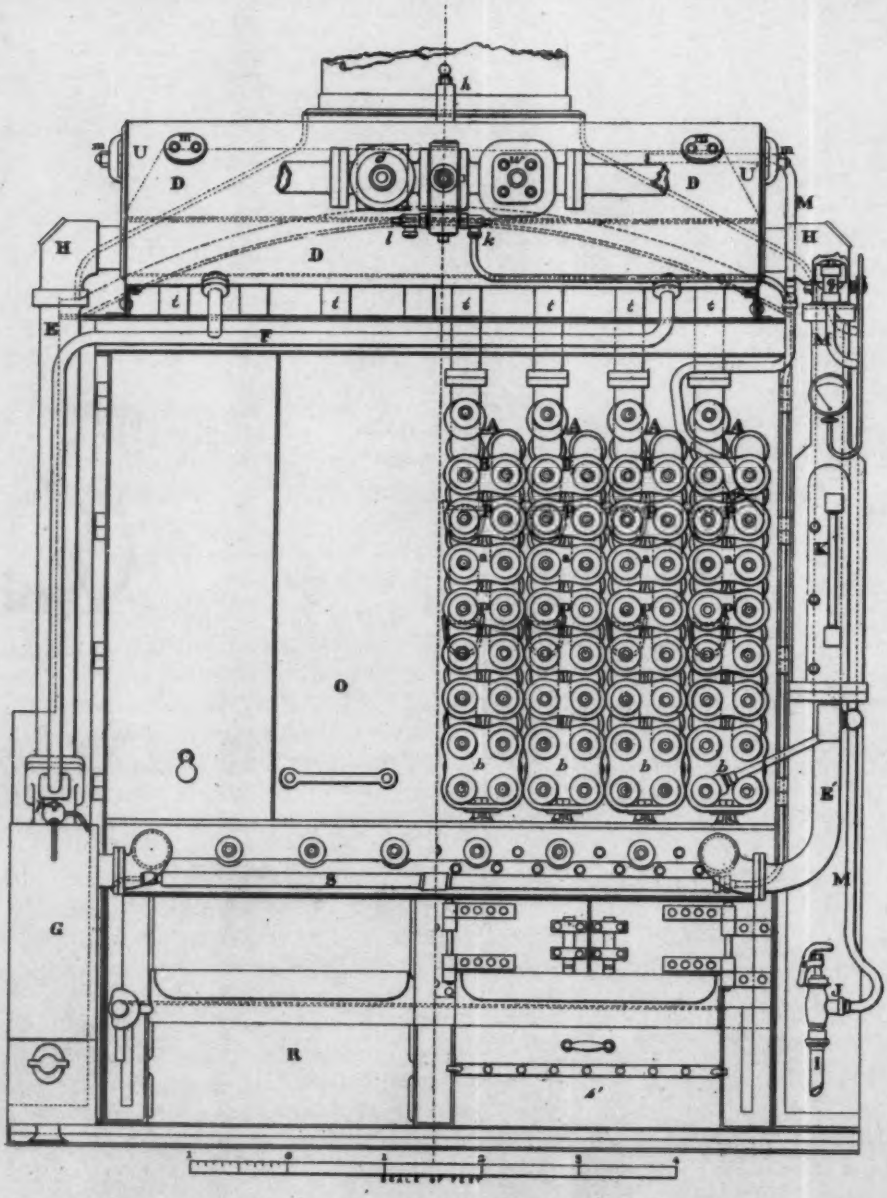
*Approximate.

The preceding table has been prepared from data of evaporative tests made at different times by Boards of U. S. Naval Engineers. The locomotive boiler test is an exception, however, it having been made in England on the boilers fitted in the Italian torpedo boats *Tripoli* and *Folgore*. Although these tests are not strictly comparable, on account of the great disparity in sizes of boiler, ratios of heating to grate surface, and variety of working, they can be taken to fairly represent the comparison intended by the writer, viz: the relative weight and space occupied by the three types of boiler—tubulous, locomotive and Scotch.

In the case of the large Ward boiler, the grate area and heating surface *used* are given; the actual areas are added below. The evaporation, apparent in each case, is from and at 212°. Where calorimetric tests were made the percentage of moisture is given.

The weight per I. H. P. is estimated on a basis of 20 lbs. of water per hour for all cases excepting the Scotch boiler, where 25 lbs. has been used, as this boiler was limited to 80 lbs pressure of steam.

The following approximation is made from the table, on the assumption that the evaporation varies directly as the combustion, and 25 lbs. of coal per square foot of grate per hour used as the unit. This assumption is manifestly unfair to those boilers using a high rate of combustion; however, leaving the *small* Ward boiler out of the comparison, it will be seen that the locomotive boiler is the only one to suffer. The *large* Ward boiler, although burning 55 lbs. of coal per square foot of grate, has approximately the same evaporation per pound of coal as the others at 25 lbs. These figures, speaking for themselves, need but little comment. The locomotive boiler should receive a favorable correction of about 20 per cent. in columns 2, 3 and 5, on account of the high rate of combustion. On the other hand, the Belleville boiler should receive an adverse correction of about 10 per cent., on account of low combustion; but even without this correction it is seen that this boiler has no practical advantage over the Scotch, either in space occupied or weight. All the other tubulous boilers given greatly *exceed* the Scotch in these advantages of weight and space.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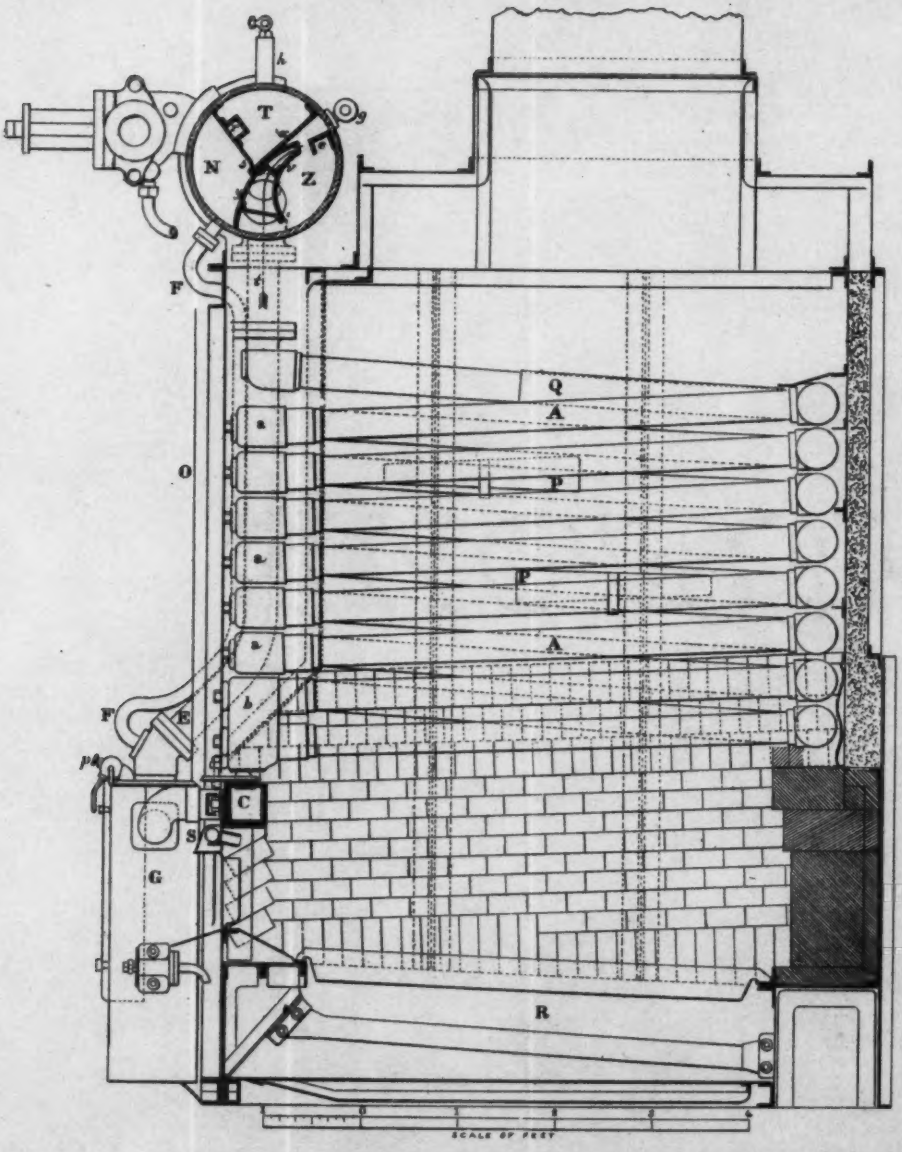

BELLEVILLE BOILER
of
Yacht Shearwater.

Type.	1 Combustion.	2 Evaporation per cu. ft. of space.	3 Weight per I. H. P.	4 Weight per sq. ft. heating surface.	5 Weight per lb. of water evaporated.
Belleville.	.5	.5	2.02	2.1	2.5
Herreshoff.	1.	.95	.72	.6	.9
Towne.	1.	1.2	1.12	.87	1.3
Scotch.	1.	.44	2.4	1.64	2.3
Locomotive.	3.9	.31	3.7	1.25	3.5
Ward.	2.2	.58	1.27	.5	1.53

THE BELLEVILLE BOILER.—This boiler, as shown on the plate, consists of a system of tubes of equal length joined together by junction boxes of malleable steel, so as to form a series of flat coils, each of which is connected to the feed-water box *C* at the lower end of the coil, and to the steam drum *D*, at its upper end. The steam drum, into which the feed water is delivered, is connected with the feed-water box and a vertical cylindrical vessel, called a sediment collector, by two outside pipes, *E* and E^1, the one on the starboard end leading direct to the feed-water box. This arrangement permits of a continuous circulation of water and steam through the tubes to the drum, and of the water from the drum to the feed-water box.

The tubes are of lap-welded wrought-iron, 3.9 inches outside diameter. The back junction boxes are simple U connections, the lowest of these boxes, *b b*, resting directly on the feed-water box, having each four openings for the reception of tubes, one opening in the lower row being blanked off; the other front junction boxes, *a a*, form simple horizontal U connections like those at the back. The lower front junction boxes have two chambers, the upper one forming a U connection, and the lower one, which receives the lower end of the last tube, connecting with the water box. On the front of each front junction box there are sight

holes, closed by wrought-iron plugs, each held in place by a single T-head bolt and nut, the joint being made with linen asbestos card board.

Each tubular element, *A A*, is complete in itself and independent. In case of any accident to a tube or tubes of an element, the latter can be readily and quickly disconnected, the connection holes blanked, and the rest of the boiler used without inconvenience. The tubes are screwed into the back junction boxes with ordinary pipe threads, and further secured by jam-nuts; at the front ends they butt against nipples, threaded similarly to the tubes, and are held in place by screw-couplings, shouldered against the faces of the boxes and secured by jam-nuts on their backs. By this arrangement any two tubes, connecting in the same back junction box, may be removed and newed without disturbing any of the others, a valuable consideration and a great convenience in case of repairs. The feed-water box is of iron, forged in rectangular section.

The interior of the drum is divided into three nearly equal compartments, *Z*, *T* and *N*, by diaphragm plates *x*, *y* and *s*, extending its whole length, bent and riveted together along a line near the axis.

The circulation in this boiler is as follows: Water passes by a pipe *I*, through a graduated check valve *J*, to the feed pipe *M*, thence to an automatic feed regulator *q*, secured to the standpipe *K*, and to which is attached the water-gauge glass. From the regulator the water passes, by means of pipe *M* (*g* in side view), to the longitudinal center of the steam drum *D*, delivering just above the shelf *e*, where it meets the steam delivered into *Z* through *t t*; here it thoroughly mixes with the steam, which is supposed to heat it sufficiently to precipitate the lime salts, which, falling to the bottom of *Z*, are carried along with the water through the pipe *E* to the sediment chamber, and by pipe E^1 to the feed-water box direct.

The water flows from the sediment collector to the feed-water box, which supplies the several series of tubes, the water and steam passing by pipes *t t t* to the chamber *Z* in the drum. The steam escapes through the triangular openings *U* and U^1 into *T*,

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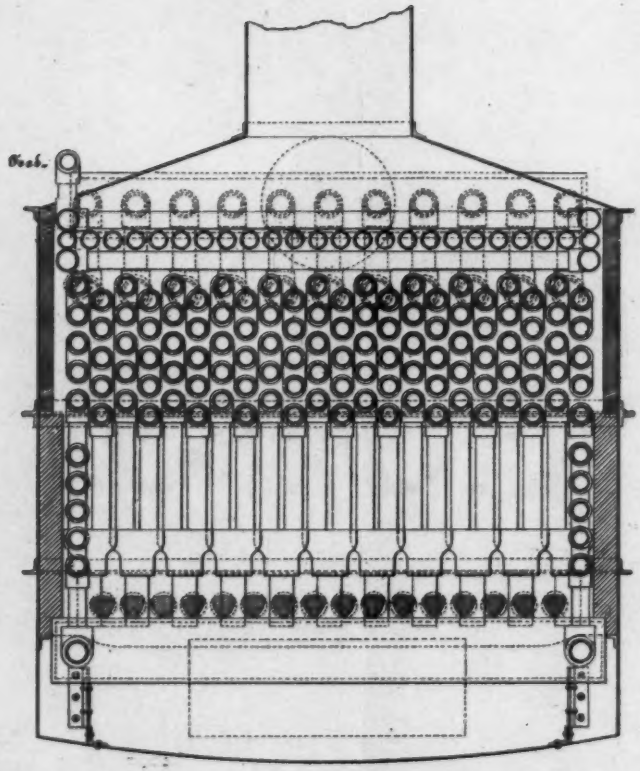
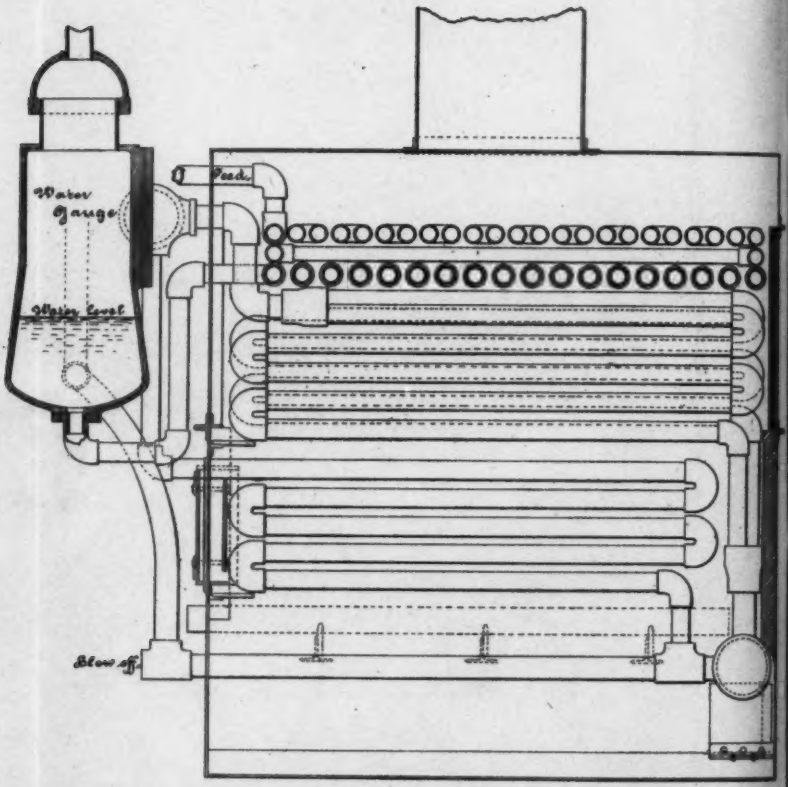


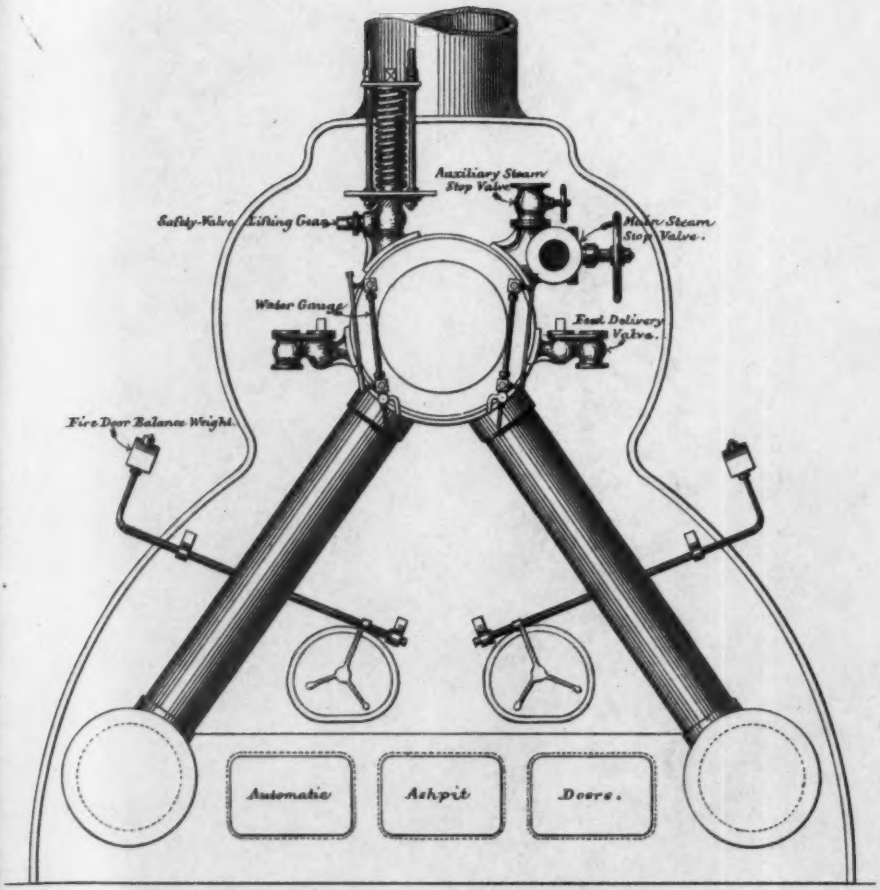


Herreshoff Boiler

New Type.

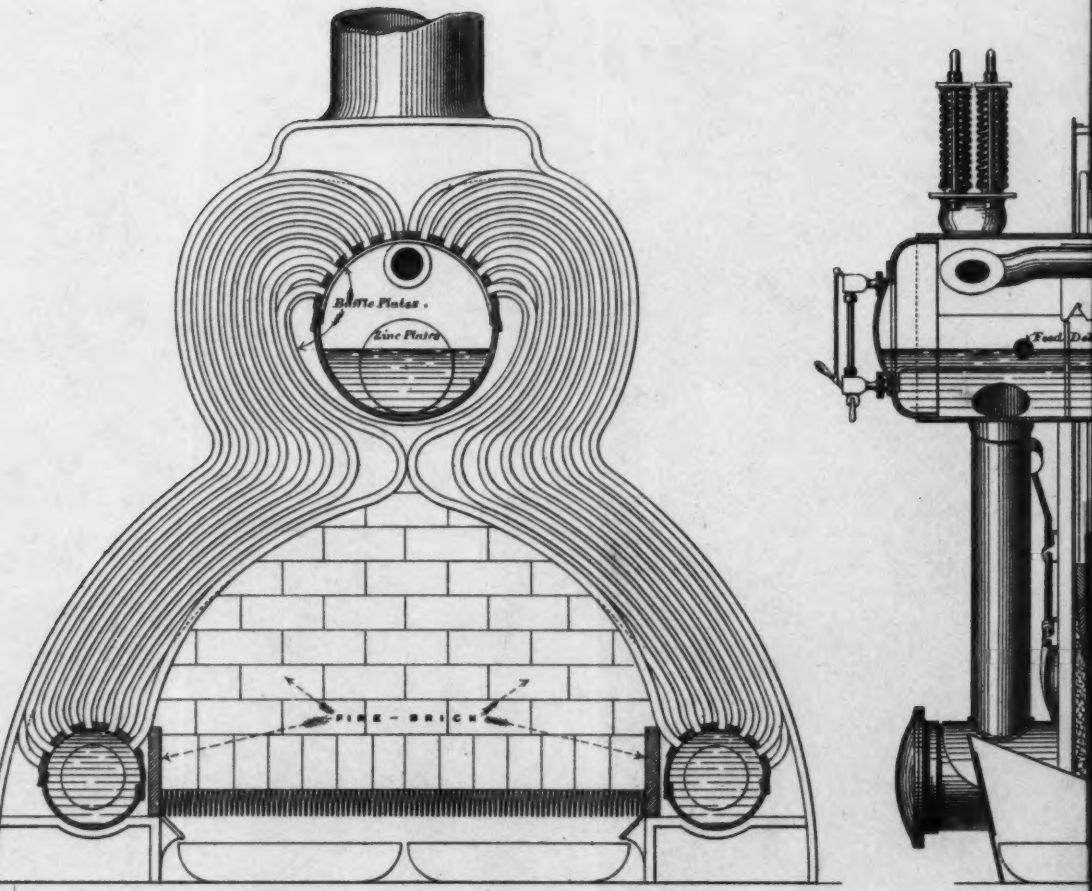
Scale of feet.

0 1 2


Auxiliary Steam Stop Valve.
Safety-Valve
Lifting Gear
Main Steam Stop Valve.
Water Gauge
Feed Delivery Valve.
Fire Door Balance Weight
Automatic
Ashpit
Doors.

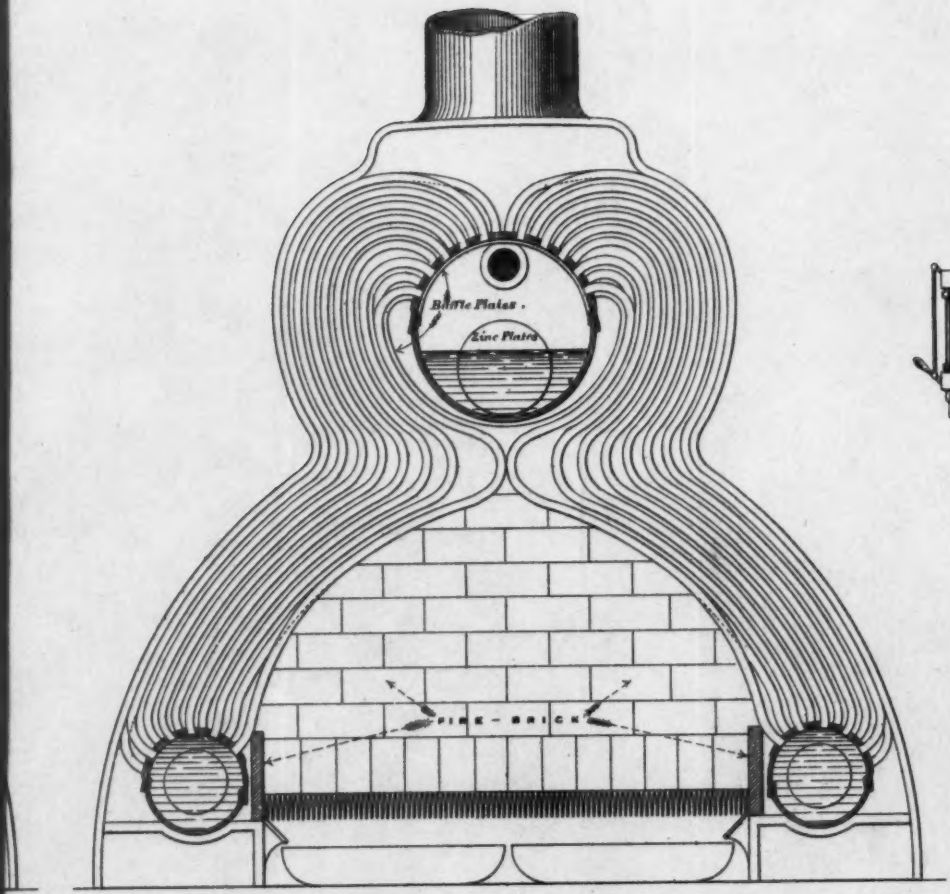
THE "T H

Index



HORNYCROFT" WATER-TUBE BOILER.

1 2 3 4 5 6 7 8 9 10 Feet.



"THORNYCROFT" WATER-TUBE BO

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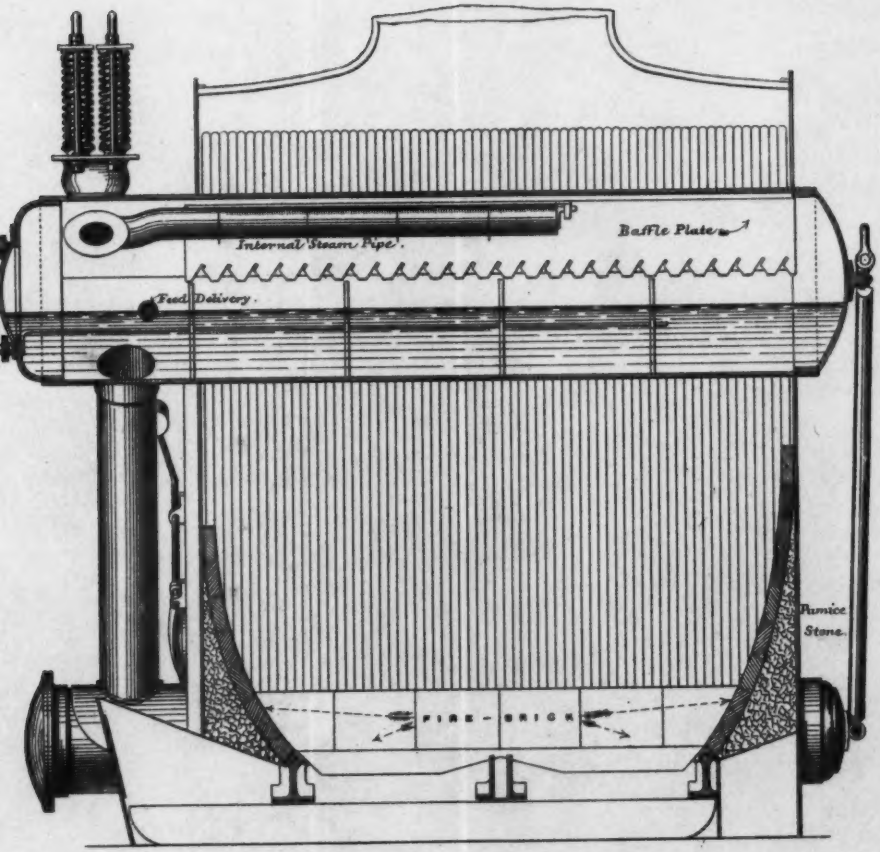
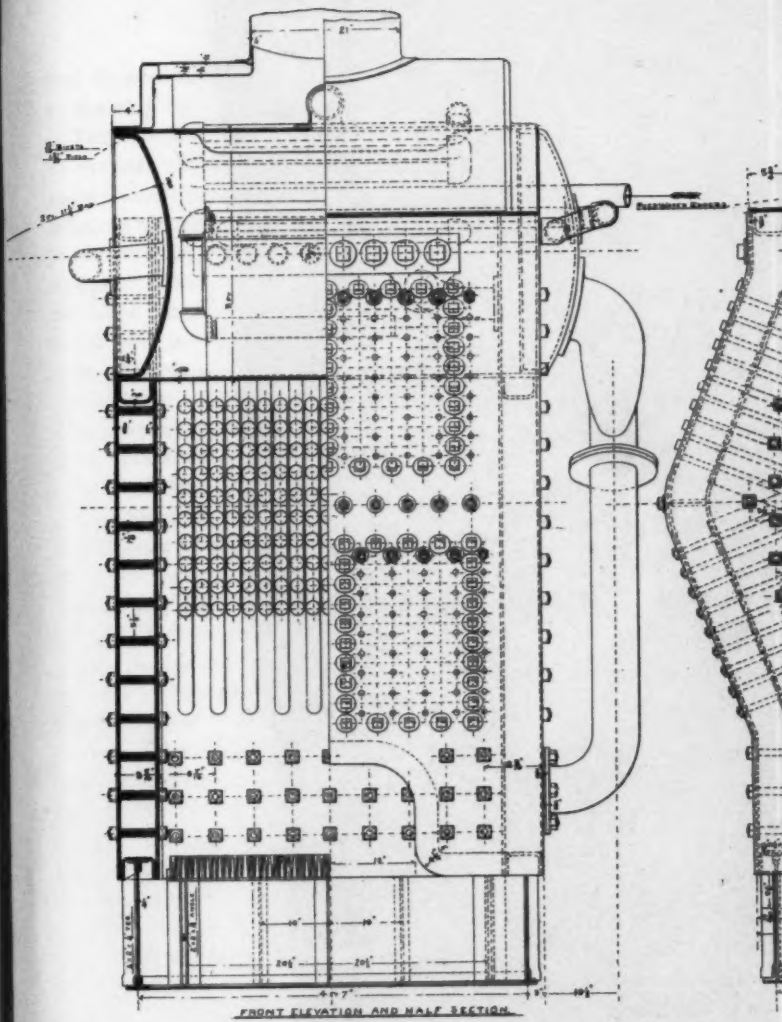

Internal Steam Pipe.
Baffle Plate.
Feed Delivery.
Pumice Stone.
FIRE - BRICK

I L E R.

Feed.



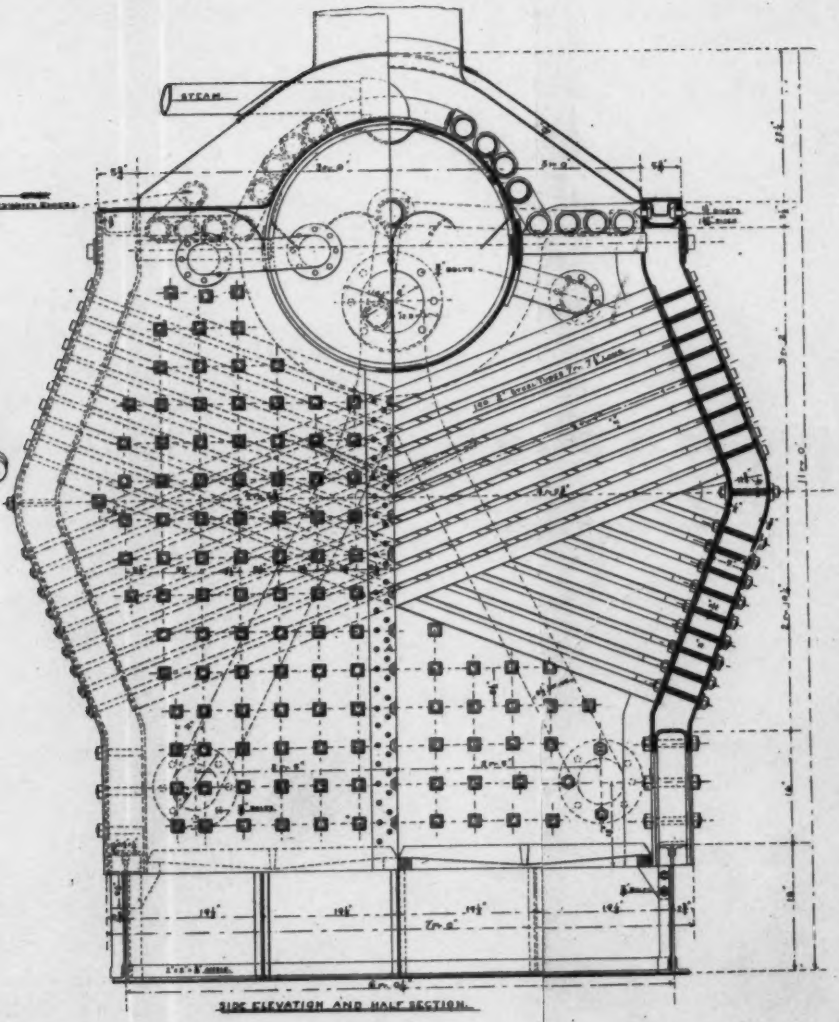
FRONT ELEVATION AND HALF SECTION.

GRATE SURFACE ..... 24 Sq Ft.

HEATING " ..... 956 " "

RATIO OF GRATE TO HEATING SURF. 1:39.83.

TOWNE B



SIDE ELEVATION AND HALF SECTION.

TOWNE BOILER

and thence through the dry pipe *r* into *N*, from which it passes to the stop valve *w*, or safety valve *d*.

THE HERRESHOFF BOILER.—This boiler consists of a number of vertical elements, each composed of horizontal tubes, with right and left-hand threads, and connected by return bends. Two adjacent elements are connected at the back and lower ends by short vertical tubes to a Y-piece, which has a short connection to a mud drum, situated below the grate bars. At the upper ends the same elements are similarly connected to a steam drum, situated just in front of the boiler casing. At each side of the grate there is an element having a connection to the steam drum, and another to the feed-water pipe near the mud drum. These side elements and the vertical connecting pipes to the mud drum serve like water legs to protect the boiler casing from the intense heat of the fire. Above the boiler proper and entirely within the casing there are three horizontal elements forming a practically continuous pipe, the tubes of which are connected to each other as in the vertical elements. These elements serve as a feed water heater and also protect the top of the casing by reducing the temperature of the gases of combustion. In front and at the upper part of the boiler is the centrifugal separator, from the top of which the main steam pipe leads to the engine, and at about the middle of which the steam drum is connected.

The upper element of the feed-water heater receives the main feed-pipe, the lower element being connected to the bottom of the separator. All the tubes of this boiler and the feed-water heater are of iron, and are separately tested before they are put in the boiler to a pressure of 1,000 pounds per square inch. The U-connections are of malleable cast-iron, carefully selected.

The circulation is as follows: The feed water enters the upper horizontal element at the point marked "Feed" on the plate; forced through these elements by the feed pump, it enters the bottom of the separator, and from there, by means of two down-cast pipes attached to the sides of the former near the bottom, it passes to the lower water chamber or mud drum at the back of the boiler; this mud drum supplying in turn the several vertical elements, which finally discharge into the side of the drum, and

thence the steam, together with any intermixed water, passes into the centrifugal separator, to the top of which the steam pipe is attached. The lower side elements draw their supply from the connecting pipes between the downcasts and mud drum, and discharge into the bottom of the steam drum, there meeting the discharge from the vertical elements. This design of boiler looks towards a complete, or nearly complete, conversion of the water into steam before it reaches the steam drum. The object of this later design is to produce a boiler which will not require as close attention to the feed supply as did the original Herreshoff coil boiler.

THE THORNYCROFT BOILER.—This boiler consists of a horizontal drum or separator at the top, placed longitudinally over the center of the grate; two smaller horizontal cylinders on either side of the grate, a number of steam generating tubes, connecting the upper part of the circumference of the smaller cylinders with that of the separator, and of two downcast pipes outside of the furnace, connecting the separator with the wing cylinders, these pipes being for the sole purpose of supplying water to the wing cylinders. The greater number of the generating tubes are arranged as shown in continuous full lines in Fig. 3, those in full lines in Fig. 2 being only the groups at each end of the boiler, which are so arranged for the purpose of protecting the ends of the casing. The separation of the steam and water is effected by a semi-circular baffle plate placed inside the separator at its upper end, and upon this plate the steam and its contained water is discharged from the generating tubes.

The circulation is as follows: The feed water enters the lower part of the separator at the front end of the boiler, thence passing to the downcast pipes at the back, it is lead to the wing cylinders, which in turn supply the generating tubes. These latter discharge into the upper semi-circumference of the steam drum or separator, the steam and water impinging directly upon the curved baffle plate previously mentioned. Directly beneath this baffle and close to the top of the drum is placed the dry pipe, leading to the stop valve on the front of the boiler. The wing

cylinders are protected from the direct heat of the furnace by the fire-bricks, which form the sides of the grate. In case of a tube giving out, it can be readily plugged from the inside of the drums, and as the heating surface is relatively large in this type of boiler, quite a number of the tubes could be so treated without seriously impairing the efficiency of the boiler.

THE TOWNE BOILER.—This boiler is of rectangular box form, as shown. It is provided with a steam drum or separator, which is connected with the boiler proper at the top by means of a series of horizontal tubes, and at the bottom by means of downcast pipes. The horizontal tubes are screwed into the drum, as shown, and expanded in the tube sheets. These latter are bent or inclined to meet the generating tubes, which make an angle of about 30° with the vertical. The spacing of these tubes will be readily understood from the plate. The screw plugs in the boiler shell permit of any defective tube being readily removed. These plugs are slightly greater in diameter than the tubes, in order to permit the use of an expander. The plugs are so made that in case they become *set* from any cause they can be readily broken if necessary to remove them. The drum is fitted with baffle plates, as shown, and is protected on its lower side by the generating tubes, and on its upper side by a coil of piping acting as a feed-water heater.

The feed enters the front of the boiler casing, near its top, and after passing through the feed-heating coil, emerges again and enters the front head of the separator, below its water level. From here, by means of downcast pipes, the water passes to the bottom of the boiler, thereby supplying the generating tubes, which in turn carry it to the top of the box section again, and thence, by means of the horizontal connecting tubes, it passes to the separator. From the top of the separator the steam passes to the main steam pipe, after passing through a baffle plate.

THE WARD BOILER.—This boiler, in its general form, is a vertical cylinder, as shown. Radiating from either side of a central vertical drum, is a row of vertical steel columns, placed at an angle of 180 degrees apart; these columns on one side of the drum rest on a horizontal manifold, their upper ends being

closed; the vertical columns on the opposite side are connected to horizontal manifolds at top and bottom. These three manifolds are connected to the central drum at their inner ends.

In a plane, slightly inclined to the horizontal, are a large number of concentric tubes, each completing a semi-circumference; there are the same number of concentric sections or nests of these tubes as there are vertical water columns. The tubes are secured to the vertical columns by means of steel bushings, with right and left-hand threads, and thus a defective tube can be readily removed.

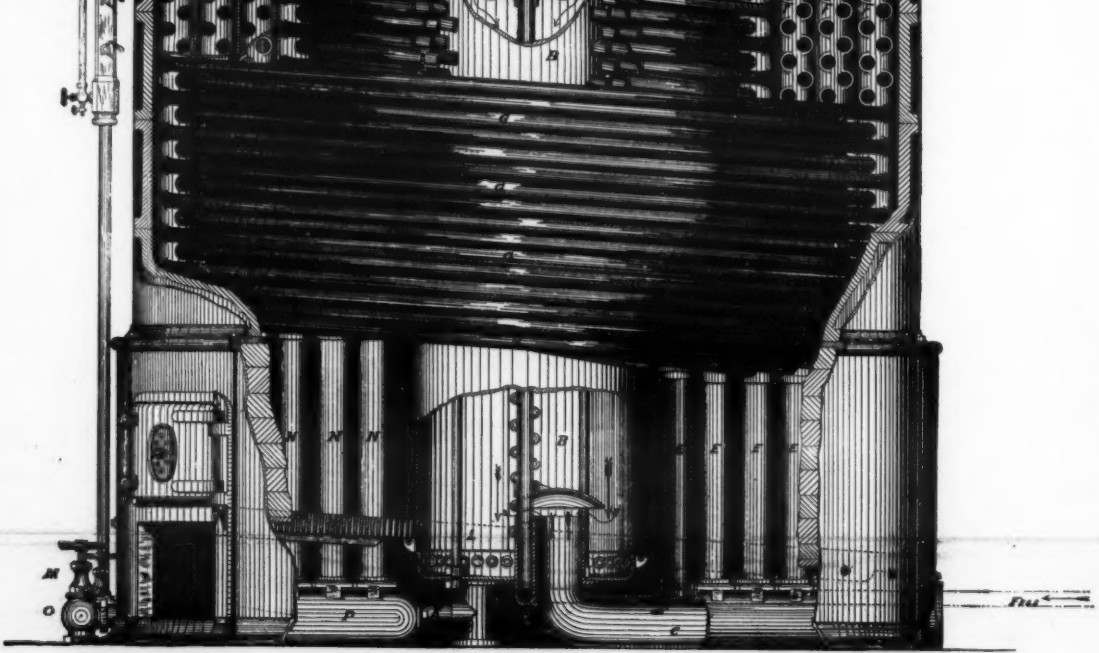
The feed water enters the base of the vertical drum, and is conducted by an internal pipe (having an inverted "rose" on its end) to about the water level in the boiler; from here it passes down the drum to supply the horizontal manifolds *C* and *P;* from manifold *P*, water passes to the vertical water columns *E, E, E,* which in turn supply the horizontal tubes; these latter discharge into the vertical columns *H, H, H,* and, together with the steam formed in these columns, flow to the upper manifold *I*, and thence to the upper part of the central drum; the steam, after passing through a baffle plate, enters the dry pipe *J*, leading to the stop valve. Any water entering the drum with the steam falls again and completes the circuit.

In this boiler every individual piece is free to expand and contract independent of any other.

By removing the top of the boiler casing and the upper manifold *I*, any of the nests of tubes may be *raised* out of the jacket for examination or repairs.

The Ward Launch Boiler.—This has recently been fitted to some of our navy launches, and is also in general form a vertical cylinder, but is radically different in its general arrangement of pipes from that of the large Ward boiler.

From a horizontal annular manifold, a double row of small water tubes rises vertically three to six feet, according to the size of the boiler, and then taking an easy sweep of 90 degrees, enters a central drum. In order to form the furnace door, a rectangular, hollow, vertical projection is cast upon the upper semi-circumference of the manifold. The interior of this pro-



WARD'S STEAM GENERATOR.

TOTAL { HEATING SURFACE 1661 / GRATE 42 } SQUARE FEET

N24.

WARD'S
STEAM GENERATOR

jection is in connection with the interior of the manifold and contains water. Upon the top of the projection for the furnace door, and upon the upper surface of the manifold, nipples are placed alternately on different diameters, so that the nipples of one row come opposite the spaces between the nipples of the other row. Into these nipples the lower ends of the two rows of vertical tubes, forming the sides of the furnace, are secured by screw couplings. The upper ends of the tubes are secured into nipples, cast on the central drum, by screw couplings, in the same manner as the lower ends. Owing to the small circumference presented by the central drum, there is not sufficient space for it to receive the tubes of the same row on the same horizontal plane; accordingly, each alternate tube of each row enters the drum on a lower plane than the remaining tubes.

The central drum consists of two portions, namely, the lower, filled with water, and the upper, filled with steam, the upper portion being a vertical extension of the lower. Both are cylindrical, and have their axes in the same vertical line with the axis of the boiler. The lower portion of the drum is of cast steel, $\frac{3}{8}$-inch thick, and upon its sides are cast the nipples into which the upper ends of the tubes are screwed. Its bottom is an inverted right cone, into which are screwed concentric rows of wrought-iron hanging tubes. The open top of these hanging tubes has a wrought-iron plug, perforated with two holes, fitted tightly into it and held in position by friction. Each of these perforations is fitted with a seamless brass tube, open at both ends. One of the tubes extends downwards into the hanging tube to within one inch of the bottom of the latter; the other extends upwards six inches on its slant height above the bottom of the lower portion of the drum.

The two brass tubes are parallel with the hanging tube, to which they are attached. The plug acts as tube plate for both.

The lower portion of the drum has an inclined partition carried entirely around it, partitioning off an annular pocket of triangular cross-section. This partition joins the vertical sides of the drum, just below the entrance of the outside row of tubes

forming the sides of the furnace, and divides the water in the lower portion of the drum into two separate portions.

The feed enters a conduit formed by a semi-circular lip turned over at the upper end of the partition, and from which it is delivered into the annular triangular cross-sectioned space formed by the partition and sides of the lower portion of the drum. From this space the water descends the *outer* row of tubes to the horizontal manifold or base ring, from which it ascends again by means of the *inner* row of tubes into the lower portion of the drum.

The water enters the brass tube inside the wrought-iron hanging tube from the lower portion of the drum, and is delivered at the bottom of the hanging tube. The water then ascends the latter, and is finally delivered from the upper end of the brass tube that is above the hanging tube into the lower portion of the drum.

The small quantity of water in the tubes relatively to their heating surface causes the circulation in this boiler to be very rapid.

As several members and associates of the Society could not contribute to the discussion in the current number, owing to lack of time, and as Mr. Coryell has promised a special article on the Belleville boiler as a continuation, the Council will be glad to receive any further remarks on the subject of tubulous boilers for insertion in the August number.

Mr. Leonard's article was sent to Messrs. Herreshoff, with an invitation to send any comments or remarks they might wish to place on record in regard to their boiler, or the general subject of tubulous boilers, but no reply has been received from them.

Discussion.

Chief Engineer B. F. Isherwood, U. S. Navy.—*Pipe boilers versus shell boilers for naval service.*—Previous to the introduction of torpedo boats into modern steam navies, and as long as the pressures in steam boilers did not exceed about

150 pounds per square inch above the atmosphere, the coal being consumed with natural draft, and as long as only moderate speeds of vessel were required, the regular marine boiler with cylindrical shell and furnaces, and with brass tubes returned horizontally above the furnaces, gave perfectly satisfactory results. These boilers were economical in vaporization, reliable and durable, and rapidly, completely and easily cleaned on both sides of the heating surfaces. The only injury they were ever likely to sustain—that of the burning out of a few upper tubes by neglecting to maintain the water at the proper level—was quickly reparable with small hand tools and unskilled labor. This damage rarely occurred, and was nearly always occasioned by inexcusable neglect, as the quantity of water above the top of the heating surface was sufficient to last under ordinary conditions for a considerable length of time, even if the feed pump failed to work.

The weight of these boilers and the space occupied by them were greater per square foot of heating surface than in the case of their immediate predecessors, the marine boilers having rectangular shells and furnaces with brass tubes returned horizontally above the latter, and a maximum steam pressure of about 40 pounds per square inch above the atmosphere, which was resisted by direct internal braces.

The length and height of the boilers with rectangular and cylindrical shells were the same, but, for equal grate surface, the latter required more breadth, owing to the lost space in the lower spandrels. The cylindrical-shelled boiler had, also, less steam room, owing to the lost space in the upper spandrels. It had likewise more restricted ash-pits and furnaces, less height of bridge wall, and less area over the bridge for the passage of the gases of combustion at their high temperature on leaving the furnace. It would, consequently, with natural draft, other things equal, burn a less weight of coal per hour per square foot of grate.

The shell of the rectangular boiler was about $\frac{5}{16}$-inch thick; that of the cylindrical boiler could be made $1\frac{8}{8}$-inch thick, so that the durability of the latter greatly exceeded the durability

of the former, on account of its resisting corrosion better. The same corrosive influence which would destroy, say $\frac{1}{16}$-inch of the thickness of a $\frac{5}{16}$-inch iron plate, would make a scarcely perceptible impression on a plate $1\frac{3}{8}$-inch thick, mass opposing a resistance of its own additional to surface. This greater durability of the thick cylindrical shell is a practical merit of the first importance.

The strength of the rectangular-shelled boiler was in its direct internal bracing, and it was impracticable to apply this system when the high pressures necessary for compound engines were required. The strength of the cylindrical-shelled boiler was in its shell, with the exception of the flat ends above the tubes and the flat water spaces between the shell and the smoke connection chambers, which could be held by short direct braces. For additional strength all that was needed was additional thickness of shell, and this could be given practically up to about $1\frac{3}{8}$ inches, beyond which the riveting became unsatisfactory, nor could welding the same be made more satisfactory. No trouble was experienced with the cylindrical furnaces, as their strength to resist compression, by means of corrugations with iron or steel no thicker than $\frac{1}{2}$-inch, greatly exceeded any strength possible to be given to the shell with even the thickest plates; and the remark may be made here that the strength of the shells increases in a less ratio than the thickness of the plate, other things equal.

The method of increasing the strength of the cylindrical shell by making the seams diagonal, say, at the angle of 45 degrees, instead of horizontal, has not been tried; but there can be no doubt that it would make the strength of the shell very nearly the strength of the plate. This method is, however, of much more difficult and costly execution than the horizontal seams; but, owing to the less thickness of plate required for equal strength, the saving in material would largely offset the greater cost of workmanship. The weight thus saved for the vessel would be an important gain.

Of course, all additions of strength due to additional thickness of plate is so much additional weight added to the boiler, and consequently to the load of the vessel. Practical considerations,

therefore, of weight and of construction appear to limit the pressures with cylindrical shelled boilers of large diameters to about 150 pounds per square inch. If the diameters be made small, great losses are incurred of space, weight and efficiency, with much additional complication of already too complicated details.

With every increase of steam pressure there goes a corresponding increase of temperature, and, of course, a corresponding increase in the radiation of heat from the shells of the boilers, which radiation is one of the greatest troubles in the fire room of a steamer, as it materially reduces the working efficiency of the firemen without including the by no means to be neglected loss of heat. The least external surface of shell is therefore much the best, and, in this particular, the rectangular shell had a decided advantage over the cylindrical shell, especially when combined with the lower steam pressure used in it. With temperatures above what is due to the pressure of about 40 pounds per square inch above the atmosphere, great difficulty is experienced in keeping the shells of boilers covered with a durable and effective non-conducting material.

With what may be termed the system of shell boilers with internal furnaces, the limit of pressure appears to be about 150 pounds per square inch above the atmosphere, and if greater pressures are demanded some other type of boiler must be found which permits the greater pressures to be carried, and its vices, whatever they may prove to be, must be endured. In the material, as in the moral world, when one more virtue is found, it is generally accompanied by two more vices.

The continual demand for higher speeds of naval vessels, and the testing of such speeds by short trials of only a few hours at the most, and, most frequently of only a few runs over a measured mile, naturally led to the employment of the forced draft, or, more properly, "mechanical" draft, for boilers, in order to burn on the same grate surface in the same time from three to four times the quantities of coal that could be burned by the natural draft of the chimney. Of course, only from one and three-quarters to twice as much steam per hour was thus obtained for the three and four times quantities of coal, but, as the

trial was to last only a very short time, and as the vessel was never expected to be steamed at any such speed afterward, this extravagant waste of coal was not considered. The point was simply to satisfy public opinion at any cost as to speed, and the trial gave authority for that, a satisfactory speed being synonymous with a satisfactory vessel, nothing being said about the impossibility of maintaining such speed, under average conditions, long enough for any useful purpose, nor about the sacrifices of other qualities made to obtain it. But there was soon found that with the employment of excessive mechanical draft the boilers suffered constant damage in their tubes, which after each brief trial leaked in their tube plates, and this result cannot be avoided. It was in vain that the tubes were again and again expanded in their plates; they only leaked the more and more. The difficulty was not due to bad workmanship, but to ignorant engineering. Evidently there was a connection between the leakage of the tubes and the quantity of coal burned per hour on the square foot of grate. When this quantity exceeded a certain limit the tubes leaked, but below that limit they remained tight. The performance of railroad locomotives was cited, in which quite as much coal is consumed per hour per square foot of grate in average practice without damage to the tubes as in the case of the marine boiler when the combustion is forced to the maximum by mechanical draft, and the inquiry has been made why this rate of combustion could be permanently maintained in the locomotive boiler without injury and without difficulty, and not in the marine boiler. As the question has not been answered, I will reply to it here.

The explanation of the mystery consists in the simple fact that for an equal quantity of heat generated on each square foot of grate, the locomotive boiler has about three times the heating surface to absorb it that the marine boiler has. In other words, taking the combustion in the case of the marine boiler with maximum natural draft as the normal, and which can be maintained without injury to the tubes, and without too much sacrifice of the economic vaporization, then, in order that these qualities may be maintained with the increased rates of combus-

tion produced by mechanical draft, the heating surface proportionally to grate must be increased proportionally to increased rate of combustion. The proper comparison is weight of coal consumed per hour per square foot of *heating* surface, and not per square foot of *grate* surface. When the comparison is made in this manner the riddle is read.

In the marine boiler the heating surface is about 25 to 1 of grate, while in the locomotive boiler the heating surface is about 75 to 1 of grate: as a result, and with equal rates of combustion per square foot of grate, each square foot of the marine boiler heating surface has three times the quantity of heat thrown upon it per hour that the locomotive boiler has, and the problem is, can the lesser surface transmit to the water without injury to itself this greater quantity of heat in equal time?

The answer to this inquiry depends on the heat-conducting quality of the metal—iron, brass or copper—of the tubes. None of these metals conduct heat instantaneously. If they did, there would be no occasion for any tubes in any boiler; the surfaces of the furnace alone would transmit to the water all the heat that could be generated in it by any rate of combustion produced by any means. But, in fact, instead of transmitting the heat instantaneously, these metals transmit it comparatively slowly, and because of this slowness of transmission a large heating surface must be provided to reduce the temperature of the gases of combustion before they leave the boiler to something like an economic limit, and for more heat generated in equal time more surface must be provided. The use of a large extent of heating surface is simply a device to obtain the time required for accepting and delivering heat. As a further result of this slowness of transmission, and the one which immediately affects the object of the present inquiry, the temperature of the metal of the heating surface or tubes is always higher than the temperature of the water which is heated, as long as the temperature of the gases of combustion is higher than the temperature of that water. Only when the quantity of heating surface is so proportioned to the quantity of heat to be absorbed that the temperature of the gases of combustion be-

comes equal to the temperature of the water before the former leaves the boiler, can the temperature of the metal and the temperature of the water be equal, after which there cannot be any transmission of heat from the former to the latter, and previous to which there was transmission due to the higher temperature of the metal.

Now, with a given heating surface in the tubes and a given temperature of water, the greater the quantity of heat thrown upon the tubes in a given time the greater will be the difference between the temperature of the metal of the tubes and the temperature of the water, the temperature of the metal becoming continually higher and higher as the quantity of heat thrown upon the tubes in equal time becomes greater and greater, while the temperature of the water remains constant. The metal of the shell of the boiler expands only by what is due to the temperature of its contained water, but the metal of the tubes expands by what is due to the temperature of that metal, a temperature always greater than the temperature of the water, and very much greater with greatly increased quantities of heat thrown on the tubes. As a result, when the temperature of the tubes has become sufficiently higher than the temperature of the shell, the difference in the expansion of the two forces the tubes through the tube plates. There must be recollected, in this connection, that the tubes are straight, rigid cylinders, firmly secured at each end into their plates, without any provision for difference of expansion, such as bellows joints, stuffing boxes or curved bends.

The higher the temperature of the metal of the tubes the less is its heat conducting power, the lessening being proportional to the increasing of the temperature counted from the absolute zero; hence the effects above described become more and more exaggerated the higher and higher the temperature of the metal; consequently they will occur the sooner, other things equal, as the temperature of the water (or pressure of the steam) is the higher, because they depend on absolute temperatures alone, not relative ones.

There is, therefore, no cause for surprise that the tubes should, in practice, be found forced through their plates when-

ever the quantity of heat thrown in a given time upon a given quantity of tube surface exceeds a certain limit determinable by practice only, and this is the limit beyond which the rate of combustion by means of mechanical draft cannot be carried in boilers whose heating surface is chiefly in rigid, straight tubes. The limit referred to is the quantity of heat due to the combustion of from 2 to 2½ pounds of coal per hour per square foot of heating surface, the temperature of the water being that which is due to steam of from 100 to 150 pounds pressure per square inch. With this rate of combustion the gases will leave the boiler at the temperature of about 1,000 degrees Fahrenheit, carrying with them more than half the heat developed by the combustion of the coal.

The opinion has been advanced that the rush of cold air into the tubes following the opening of the furnace door for firing and cleaning the fires causes the leakage of the tubes by suddenly contracting them. This opinion is entirely fallacious, no such effect could or does follow the admission of the cold air, and the persons advancing it forget that locomotive boilers have furnace doors which require to be opened just as much as those of marine boilers, and that no injurious effects result. The cold air referred to has absolutely no influence on the leakage of the tubes by contracting them. It cannot reduce their length to even the length they had when the fires were lighted. The metal of the tubes can be stretched by a force enormously less than that by which it can be compressed. Contraction is a pull or stretching force in this case, and the tube joint can resist it; but expansion is a push or compressing force, and the tube joint cannot resist it.

The following proposition now occurs: If the increased rate of combustion per square foot of grate by means of mechanical draft is desired beyond the foregoing described limiting point for straight-tubed shell boilers, then increase the ratio of the heating surface to the grate. To do this, however, is to increase the weight and bulk of the boiler, not indeed proportionally, but largely, an increase found to be inadmissible with marine boilers. If the weight and bulk of the boiler had to be increased proportionally to the increased rate of combustion above the limiting

point referred to, the advantages due to the use of the additional mechanical draft would be considerably lessened.

There is another cause that limits the maximum rate of combustion in steam boilers apart from the injury to the tubes, namely, the priming or foaming of boilers, which, other things equal, increases with greater production of steam in equal times. When steam is generated in a given boiler the mass of what was water in the cold state becomes a mixture of water and steam, having the appearance of foam or froth. The priming or foaming, other things equal, holds some relation to the proportions of the constituents of the mixture; the more steam in it the more is the priming or foaming. When the proportion of steam passes a certain percentage in the mixture the foaming becomes so excessive that no further increase can be had and the engine continue to work with safety. The greater the rate of production of steam in a boiler, the greater and higher should be the steam room—especially higher. With the usual proportion of steam room given to steam boilers, and with steam pressures of from 100 to 150 pounds per square inch above the atmosphere, used with an expansion of from 5 to 10 times, a rate of combustion of from 2 to 2½ pounds of coal per square foot of heating surface per hour is accompanied by as much foaming or priming as the engine can bear, and the economy of the fuel is greatly lessened thereby; indeed, the "priming" limit is generally reached much sooner. The overheating of the metal of the tubes is also much accelerated by greater proportions of steam in the mixture of steam and water with which the tubes are in contact. Other things being equal, the higher the steam pressure, the greater the measure of expansion with which the steam is used, and the less the reciprocating speed of the piston, the less will be the priming or foaming. Increasing the steam room increases the bulk and weight of the boiler, and, in the case of naval vessels, the increased height cannot be had and the boilers kept below the water line of the vessel. The priming of boilers is very troublesome and far-reaching in its evil effects, influencing both the power developed and the economy with which it is developed.

The weight, bulk and various limitations of the cylindrical

shell boiler with internal furnaces and straight tubes returned above them, especially for small vessels of great speed in which the proportion of power to speed is immensely higher than in the case of large vessels, and in which the proportion of resistance to displacement or capacity to carry power is also immensely higher, made a pressing necessity for a type of boiler with which more steam in proportion to its weight and bulk could be obtained in a given time, and steam of a higher pressure carried. The requirement seemed to be answered by the "pipe" boiler, of which a number of examples have been produced that were quite successful under the conditions in which they have been tried.

This type of boiler for marine use consists of an assemblage of iron pipes of small diameter arranged over the furnace, the dimensions of the latter from outside to outside of its walls being the space occupied on the floor of the vessel, and, as pipe boilers with this limitation have been as successful as other pipe boilers occupying more surface on the floor, the choice, if possible, should be restricted to them, providing equal area of heating surface is secured.

The pipes are connected with screw joints, and the design can be easily arranged to allow even more expansion than practice requires, so that there is no difficulty from this cause. The water and steam is contained within the pipes, and this fact secures the joints, with even common workmanship, perfectly tight under the highest pressures; in fact, the higher the pressure the tighter will be the joint, due to the stretching outward of the metal of the pipe by the internal pressure. When both ends of the pipes are rigidly fixed, expansion has been successfully provided for by curving them. A *sine qua non* of this kind of boiler is that it will function properly with a rate of combustion of not less than 60 pounds of coal per hour per square foot of grate, which admits the use of mechanical draft to the greatest extent judiciously desirable. A separate cylindrical vessel has to be added for furnishing steam room and for separating the steam from the water. The sides of the furnace are, of course, of brick masonry, and the assemblage of pipes is in-

closed by a casing of thin iron plate covered with non-heat-conducting material.

In this type of boiler there is neither shell, bracing, nor riveting, all the weight of which is saved, the substitute being merely the masonry of the furnace and the thin plate of iron enveloping the pipes. The quantity of water carried is only what is needed to fill the pipes, a very small quantity comparatively with that of a shell boiler, and, consequently, a great saving of weight is obtained in this particular, with the further advantage that the time needed to raise steam is reduced proportionally to the reduced weight of water. A boiler as above described consists merely of furnace, heating surface, and steam room, the heating surface being of the thinnest and the strength being a maximum, owing to the small diameter of the pipes.

For equal grate surface, such a boiler, with its contained water, weighs about half as much as the cylindrical shell boiler with its water, and occupies considerably less surface on the floor. The saving in space for a naval vessel is of much more importance than the saving in weight, as it is easier to provide displacement than to furnish available room. The economic and potential vaporizations of the two types for equal rates of combustion in proportion to heating surface can be made equal, and the priming in the one type need not be more than that in the other. The money cost of the pipe boiler should not exceed one-half the money cost of the shell boiler. The time required for its construction should not be one-fourth the time needed for the shell boiler, as the small pipes are simply screwed together, the only tools needed being "pipe tongs." A steam pressure can be carried in the pipe boiler with safety, from two to three times greater than in the shell boiler, if found more economical.

From the above comparison of the qualities of the pipe and of the cylindrical shell boiler, there would seem to be no reason why the pipe boiler should not immediately supersede the shell boiler, nevertheless, although the pipe boiler has been known for many years and its merits admitted, it has not been successfully introduced into sea-going vessels. It has been used

with entire success in small yachts, launches, vedette boats, torpedo boats, etc., almost to the exclusion of shell boilers, and has enabled such vessels to attain a speed not possible with the latter; but the service of such vessels is very brief; they are used only at considerable intervals and then for only a few consecutive hours. There is generally but one boiler in them, with sufficient space entirely around it, and it is of a size which allows one man to easily keep it dry, clean, and in good order. It can be examined and repaired without spending much time or labor on it. The corrosive influences against it are small, as the vessels are quite open to the air and well ventilated in every part, and it is possible to cover its casing with a thickness of plaster of Paris, mineral wool, asbestos, or other durable non-heat-conducting material that will reduce the radiation to an insignificant quantity. This covering being everywhere in sight and reach, can be kept always in good repair. With a boiler not much larger than a large cooking stove, the conditions of thorough care are very different from those of large boilers in the constantly moist atmosphere of the closed holds of large vessels, and so crowded that only the fronts are accessible. In this case the corrosive influences become very effective, and rapidly attack the heating surfaces and the casing, all of which are of very thin wrought-iron plate. The corrosion is almost wholly on the fire side, and is due to the soot and fine ash deposited on the heating surfaces, absorbing the sulphur gases produced by the combustion of the coal. The condensed sulphur gases become rapidly changed into sulphuric acid by combination with the moisture of the air. The sea air is also corrosive by reason of the sea water salts mechanically suspended in it, and alone acts vigorously on the iron. The sea water is most corrosive of all. Common iron stoves, in which wood soaked in sea water and afterwards dried is consumed, rapidly corrode out, while the same stoves last indefinitely when burning ordinary wood from the forest.

All experience in naval engineering shows that iron tubes in shell boilers become so corroded under these conditions, that replacement has to begin in about a year, and that at the end of

about two years all have been renewed. Now, these tubes are easily, rapidly and completely swept of ash and soot from the boiler room. The soot is upon their inner surfaces where the iron has been the least broken by the bending, while in the case of the pipe boilers the soot and ash are deposited upon the outer surfaces of the pipes where the iron has been much more injured by the bending. Because of this rapid corrosion of iron tubes in the boilers of sea-going vessels, brass tubes have been exclusively used for the last third of a century in the boilers of all naval vessels of all countries.

When large pipe boilers are placed in crowded groups in the holds of sea-going vessels, poorly ventilated, dimly lighted, insupportably hot, and closely boxed up in all directions, and with an engineering staff barely able in numbers to perform the regular steaming duties, the keeping of the heating surfaces free of ash and soot is impossible. These surfaces are practically inaccessible, they cannot be cleaned or examined, and when a pipe leaks from any cause, the leak, generally, cannot be located. The renewal of corroded or ruptured pipes in many parts of the boiler will be very difficult, and generally impossible, without removing it from the vessel and stripping off its casing. The screw joints seem easy to make and unmake, but after they have been exposed to a high temperature for considerable time, the metal undergoes molecular change, and, in general, the pipes have to be cut apart and the threads dug out. Wherever iron comes in contact with iron, moisture being present, they will rust together.

Probably these causes have prevented thus far the successful introduction of large pipe boilers into sea-going vessels, notwithstanding their manifestly great advantages, for especially in naval vessels reliability and durability take precedence of all other qualities. The pipe boiler will have to prove by extended experience that it is as durable and as reliable as the shell boiler with brass tubes, under the actual conditions of naval service, before it can supersede the latter, and the experiment, if made at all in naval vessels, should be made tentatively, and first in a small steamer on home service. The

belief—whether false or true—that greater economy of fuel can be had by the use of excessively high pressures, and the fact that such pressures can be had only with pipe boilers, will, no doubt, cause them to be soon thoroughly tried in the merchant as well as in the naval service. A form of pipe boiler may thus eventually be evolved, which, retaining the undoubted merits of the type, avoids its defects.

Thus the lighter weight of the pipe boiler, due to its construction of very thin iron throughout—one of its greatest merits—is accompanied as an inevitable result by lessened reliability and durability. The durability will, under the same conditions, probably be about, or rather less, than that of the iron tubes in a shell boiler. The iron pipes, though possessed of the requisite strength when new and properly welded, do not have that strength when corroded, nor are the welds reliable. They are often very weak spots.

The small weight of water carried in the pipe boiler—another great merit—has the disadvantage that the pumps must be incessantly watched, for an undetected failure in this respect soon causes the burning out of the pipes, and danger to life, limb and property.

The compactness of the heating surface is at the expense of accessibility, which, preventing examination, allows failure of the boiler to come suddenly and unsuspected, and no precautions can be taken against it.

The one additional virtue in this, as in all other cases, has its two additional vices, which are indeed its shadow, and probably inseparable from it.

There is no reason for believing that a boiler, which may be admirable on a small scale and under specially favorable conditions, will therefore be equally successful on a large scale and under changed conditions. Boilers, like other things, have their limitations, and these limitations can only be ascertained by experience on the large scale continued through considerable time and under the exact conditions of practice.

In this connection, attention may be called to an excellent pipe boiler, which seems to be forgotten, invented by Thomas Pros-

ser, and experimented with by me in the city of New York, for the Navy Department, during April and May of 1859—thirty years ago. This boiler is admirably designed, and its construction may be still studied with advantage. An engraving of it, and an account of the experiments made with it, will be found in the second volume of "Engineering Precedents," published in 1859.

PASSED ASSISTANT ENGINEER CHAS. H. MANNING, U. S. NAVY (RETIRED).—I have read Mr. Leonard's paper with considerable interest, and, with full knowledge of my chance of being laughed at as one who has been ashore too long to know what going to sea is, I venture to remark that, in seeking for the solution of the problem of the sea-going high-pressure boiler of the future, the merits of the vertical tubular boiler have been entirely overlooked, and in my opinion they are worthy of a trial.

They certainly would be unsuited for light draught vessels, but for some of the larger deep draught "protected-cruiser" or "battle-ship" types, I believe they could be used with great success. The type of boiler I refer to I have introduced into many of the cotton mills of New England and the Middle States with great success, and, with slight modifications, I believe they could be applied to marine use, especially in the merchant service.

The boiler has a six-foot circular grate surrounded, except at furnace door, with a water leg; the fire box is about four feet high, above which a reverse flange reduces the diameter of shell to five feet. The tubes, about 180 in number, are $2\frac{1}{2}$ inches in diameter and 15 feet long. There is no trouble in building such a boiler to withstand 250 pounds working pressure, and its advantages are many; chief among these is the readiness with which the degree of superheating can be governed by varying the water level. Its efficiency is the same as that given in Mr. Leonard's paper for the Thornycroft boiler.

Some day I will try to give the readers of this valuable journal some further information about this boiler.

CHIEF ENGINEER CHARLES H. LORING, U. S. NAVY.—Undoubtedly the great want of modern marine engineering practice is a good pipe or tubulous boiler, not only to meet the requirements

of higher pressures, but also the demand for reduced weight. Whether one has yet been produced that will satisfactorily meet the new conditions is for the moment an open question. The recently reported performance of the Thornycroft boiler seems to indicate that it has been found, and there is reason for hopefulness in the results of a recent trial of the Ward boiler, though they were by no means as extraordinary as those reported by Professor Kennedy.

Statements made by Professor Kennedy on any matters submitted to his observation and judgment are to be received with great confidence, but it is to be regretted that the statement of these results was unaccompanied by detailed relation of the manner of making the tests, whereby the professional reader could draw his own conclusions. It is one of the privileges of our profession to doubt the extraordinary when confirmatory evidence is lacking; and so the very figures of the table quoted, showing so large a quantity of water per ~~pound of coal~~, warrants the inquiry as to what could have been the character of the steam delivered, as to moisture.

The hydrous character of the steam produced is a very important factor in the determination of a generator's efficiency. No mere guess of the unaided senses can even approximately establish it. Under my notice, a large pump was supplied with steam having at times fifteen per cent. of moisture, through an uncovered pipe, out of doors, 200 feet long, without giving any indication of such a condition. So it is easy to believe, in the absence of any information to the contrary, and with the confirmatory evidence before referred to, that a very considerable amount of the apparent evaporation of the Thornycroft boiler may have been water. And so, too, one needs confirmatory evidence of the accuracy of the percentages given under the head of moisture in the large table of the paper under discussion. As in the text it is stated that they are given "where calorimetric tests were made," one is led to believe that some of them are intruders by some inadvertence. It is not too much to say that, as they now stand, they are misleading.

With the general tone of this paper, favorable to tubulous

boilers, I am in full accord. It seems as though in some form it is the marine boiler of the future. But it must not be expected to fill thoroughly all the conditions. Some of them antagonize each other beyond reconciliation. The faultless boiler will never be designed. With present experience, it may be said in general of a pipe boiler that while "danger from explosion is greatly reduced," liability thereto is largely increased, in some ratio to the lineal feet of tubing used.

An automatic feed is the device of the devil. It works well as long as you don't trust it. The moment it gains your confidence it goes back on you. Nothing short of human intelligence can be entrusted with this important duty.

The test of the Ward boiler by "the Coil Boiler Board" was very successfully accomplished with the results given in the table. There was no hitch or delay in its execution that came from any peculiarity of the boiler itself, nor was there any evidence of undue stress on any part thereof. The fire room enclosed one-half of the boiler to the height of seven or eight feet, and the radiation was so slight that the temperature within it was never more than ten degrees above that of the air forced into it by the blower. The fires were not cleaned during the runs, however. I may say, without violating official proprieties, that the Board was much pleased with it. Its liability to damage from the bulging of the central drum at the furnace level may, I believe, be avoided by placing another drum within it, thereby dividing the ascending from the descending currents, increasing the velocity of the former, and sweeping away the globules of steam that lie on the inner surface of the drum.

The approximations of the small table at the end of the article would, in my opinion, have been far more just as comparisons had they been based on the heating surface, instead of on the grate surface. Obviously the more rapid the combustion the greater the advantage of larger heating surface. Therefore the rate of combustion per unit of H. S. is very important in regard to economy, while, within limitations, the rate per unit of grate is not.

In conclusion, I would propose this question for consideration

(and discussion, if the Council approves): "May it be expected in calorimetric tests, with a barrel calorimeter, that the steam passing into the water in the barrel is a fair sample of that furnished by the boiler and delivered into the main pipe, if the branch pipe leading to the calorimeter has its sectional area, at a point remote from its connection with the main pipe, reduced to about one sixty-fourth of its normal area; and should not the weight of the contained water in the barrel be kept the same for each of a long and continuous series of tests?"

PASSED ASSISTANT ENGINEER H. N. STEVENSON, U. S. NAVY.—My experience with two Herreshoff coil boilers (square) during three seasons of coast survey work was very similar to the writer's. Breaks occurred with such frequency as to show that the boilers were unreliable, and were the cause of much anxiety. The boats were often required to make long trips, and to remain away from the ship for several days at a time. The breaks occurred in the coils above those nearest the fire in all cases but one, when a pipe in the lowest coil over the hottest fire split during the second season's use. The breaks varied from very small ones to splits five inches long, and in every case the pipes showed signs of corrosion or pitting. When the hole could not be tapped and plugged as mentioned, it was necessary, in order to reach the break, to begin at one side of a section and destroy the pipes until the break was reached, so as to save the bends and junction elbows, for the pipes could not be unscrewed from them if they had been much in use, unless they were heated very hot in a fire. They lasted many operations of this kind. New pipes were required with each repair, in addition to those broken.

It was, as the author mentions, very difficult to keep the coil clean, and, unless it was so kept, the ability to make steam was greatly lessened, the soot in a short time becoming so hard that the coils had to be taken out of the casing and scraped to remove it. After the first season's experience it was found best to construct complete new coils during the time that the ship was laid up each winter for overhauling; and, at the end of two years, each boiler had to have a new casing and smoke pipe, which were made of heavier material than the old. The Herreshoff

boiler requires very close attention and more than the average skill on the part of the attendant, and, in many important particulars, fails to answer the requirements of a perfect boiler.

MR. CHARLES WARD, ASSOCIATE.—Most progressive engineers realize and admit that the time has come when a boiler of increased steaming capacity, occupying less space, of much less weight, capable of carrying much higher pressure, and of being safely forced for emergencies, is an absolute necessity. The numerous disasters of the old type of boiler, when worked under these conditions, make a change imperative.

The points to be secured seem, with our present knowledge, only attainable in a sectional water-tube type, and recent experience justifies this conclusion. The first and absolutely essential point is such circulation of water as shall readily absorb as much of the heat of the fire as practicable, however much it may be forced. In doing this, the design should be such that the flow of water shall go on with the least resistance from change of direction, in connection with a system of separation of steam and foreign matter from the water, so as not only to effectually prevent injury to any part of the boiler from heat, but also from deposit of solid matter resulting from evaporation. This must all be accomplished in such a manner as to insure the boiler being manufactured on a system of duplicate parts, easily attached or removed—all parts being so designed that the least possible material shall give the greatest strength—advantage being taken of the best known condition of combustion with convenience and accessibility for firing, and admitting at the same time of much more ample ash-pit than is admissible in internally fired or Scotch boilers. It has been my effort—the result of several years' study and experiment—to combine these with all other essentials in the two types of water-tube boiler I manufacture.

We have built more than 24,800 I. H. P., all working under the varying conditions of every-day duty, some in fresh water, many in salt water, some of which have shown most exceptional duty. The oldest Ward boiler is now between ten and eleven years old; it was formerly on a side-wheel river

packet, which made a daily run of one hundred and twenty miles, and upwards of fifty landings per day. This boat was dismantled, and the boiler and machinery sold to the Engineer Corps of the War Department, who, in 1881, built a tow-boat, placing the machinery and boiler thereon. She has been in constant use, and is now carrying 150 pounds to 180 pounds steam, as required. Boiler-heating surface, 700 square feet; grate, 32 square feet. Two engines $12\frac{1}{4}''$ x $48''$, slide valve, poppet cut-off, $\frac{3}{4}$ stroke, and revolutions 27 to 28. The repairs on this boiler have not cost one hundred dollars during ten years of constant service; for five years just past, not a dollar has been spent on it. This would indicate that, with due care, these boilers are as long-lived as any. This, however, depends on their management, especially when in contact with salt water, though there is no reason why, with proper attention, water-tube boilers should not outlast all others, and certainly cost less when repairs are needed. For equal care, it is difficult to see why a given thickness of iron will not last as long in a water-tube as in a Scotch boiler.

In one case we removed a marine boiler weighing, including water, forty-eight (48) tons, and substituted a Ward of thirteen (13) tons, increasing the speed of the boat by from one and one-half to two knots on less coal. The former boiler was a constant source of annoying repairs; the Ward boiler was used three and one-half years without any repairs. These are not isolated cases, but only quoted to show results. The total repairs furnished for these 24,800 I. H. P. extending over ten years will not aggregate two thousand dollars.

It is, I believe, admitted that greater economy is attainable by the water-tube boiler than any other. This has been fairly demonstrated with stationary boilers, and there is no reason apparent why like results should not follow in marine use. We are, however, always skeptical regarding such figures as those given by Prof. Kennedy in his report on the Thornycroft boiler for evaporation, viz: 13.4 pounds of water per pound of coal. For the sake of illustration, suppose we find the amount of water required by the engine per I. H. P. from the evaporation per lb. of

coal and the pounds of coal per I. H. P.; we have as follows: multiplying column 3 by column 4, result, column 6:

1 Air pressure in inches of water.	2 I. H. P.	3 Lbs. of water per lb. of coal.	4 Lbs. of coal per I. H. P.	5 Temperature of chimney.	6 Engine—lbs. water per H. P.
0.00	89	13.4	2.28	421°	30.55
0.27	282	12.48	1.98	——	24.71
0.49	449	12.00	1.99	——	23.88
2.00	773	10.29	2.26	777°	23.25

While Prof. Kennedy makes a good showing (column 3) for the boiler, it is doubtful if Mr. Thornycroft will enjoy the apparent cormorant requirements of his engine, as shown by column 6.

Owing to the small space required for a very large Ward boiler, we have not placed many in battery. Their sizes range from 1,000 to 3,000 sq. ft. of heating surface each, so that we get large power in a single boiler. There are, however, two steamers, having each two Ward boilers, both stern-wheel boats. The steamer *City of Long Branch* has two boilers aggregating 3,266 sq. ft. heatting surface and 84 sq. ft. of grate, furnishing steam for two high-pressure condensing engines 18″ diameter, 84″ stroke, 25 revolutions, with steam at 180 lbs., cut off at $\frac{5}{8}$ stroke. This boat has been running seven years. The other steamer is the U. S. towboat *Titan*, used by Engineer Corps, U. S. Army, on the improvement of the Mississippi River. She has two Ward boilers, size O-24; total heating surface, 3,240 sq. ft.; grate, 106 sq. ft.; engines, 14″ diameter, 84″ stroke. Steam is furnished for these engines at 200 lbs. when following $\frac{7}{8}$ the stroke and making 28 revolutions. One boiler runs the boat at $\frac{1}{2}$ cut off. This boat furnishes excellent proof of the efficient circulation in the Ward boiler by keeping itself absolutely free from deposit when using

the muddy Mississippi water, while the old type has to use "sweeps" to prevent the deposit of the mud, which results in the frequent burning of the boiler.

These instances seem to prove that these boilers may be worked in battery, which conclusion is justified by the large number of water-tube boilers in battery at the New York Steam Heat and Power Company stations.

The Ward boiler is not exempt from all "the ills that flesh is heir to," but with proper care it is more free from trouble than perhaps any other boiler. There are no crown sheets to let down, no leaky flues or joints to give trouble, and no yielding of the tube plate, which has been so disastrous with the locomotive marine boiler. The Ward boilers were in use eight years before any one showed any trouble from grease or oil, and it was reserved for the U. S. Revenue steamer *Manhattan* to develop the first ill effect from grease. The boiler on this boat was under steam for the first time September 22, 1888. After being in use until February 16, 1889—about five months—a bulge appeared in the central drum, which resulted from the excessive use of oil, possibly unsuited to the purpose, as a hard, oily deposit was found inside the drum. It is worthy of attention that nearly five months elapsed before there was sufficient accumulation to cause the bulging, notwithstanding the fact that there were two sight-feed oil cups on the engine and no means of eliminating the grease from the feed water. Experience with this matter shows that an occasional boiling out with good potash entirely removes the evil.

This experience suggests an investigation as to how far oil is necessary in the cylinders of engines, and, if necessary, what oil is most suitable to the engines and least injurious to the boilers. In this connection I submit the following extract from results of experiments by the French scientist, M. Hirsch, as to the effect, as regards overheating of the plates, of oily deposits, incrustation and water containing solids in a state of fine suspension. The extract is from *Power and Steam:*

OVERHEATING IN THE FIRE SURFACES OF BOILERS.—Many accidents have occurred from overheating when the man in

charge has been morally certain that the boiler contained water enough to cover sheets at the level at which the action occurred. In this connection the following results of experiments by Mr. Hirsch will be read with interest.

A circular sheet of wrought iron about 16 inches in diameter and $\frac{4}{10}$ of an inch thick was attached to a copper cylinder forming an open-topped boiler and set in a furnace of fire clay, in which an intense fire was maintained by gas burned with a blast. The temperature of the plate was measured by inserting plugs of fusible alloys whose melting points were known.

As the evaporative rate increased the difference between the temperature of the external surface of this plate and the temperature of the water upon the other side was found to rise progressively, being 212° for an evaporative rate of 41 pounds per square foot of heating surface per hour, and not above 302° for an evaporative rate of 61 pounds. From this it is to be inferred that with clean sheets to which the water has ready access, little danger exists of overheating at rates of evaporation far exceeding those used in practice. Where braces and riveted seams prevent the direct access of water to the sheet, or where by reason of contracted passages for its escape steam is retained upon the surfaces upon which it is formed, preventing the rapid, continuous and constant inflow of water upon them, this danger may continue to exist.

The preceding experiment, which was made with distilled water, was then repeated, using water containing from .002 to .005 parts by weight of starch. With the lesser amount the temperature of the fire surface of the plate was increased about 27°, and went but little higher at the maximum amount. As this exceeds the proportion of starchy matter usually used for the prevention of scale, overheating from this cause does not appear likely, so long as the substance is kept diffused in the water.

Several experiments were made after covering the plate on the interior surface with thin coats of plaster of Paris. For a thickness of 0.04 in. the temperature of the external surface was about 54 degrees higher than was found for the plate in direct contact with distilled water. Coating the plate to a thickness of 0.2 in., its external surface had a temperature of 450 degrees for an evaporative rate of 32 pounds, and a temperature of 720 degrees for an evaporative rate of 41 pounds. These figures are, respectively, 63 and 378 degrees above the temperatures obtained with clean plate in contact with distilled water. They show clearly the bad effect of incrustations.

To determine the effect of changes in the thickness of a plate due to seams or deposits, a sheet of steel, 0.2 in. in thickness, was soldered to the plate. The temperature of the external surface of the plate was increased 90 degrees for an evaporative rate of 21 pounds, and 126 degrees for an evaporative rate of 61 pounds, over the temperature obtained with the plain plate. This seems to indicate that there is some danger in exposing riveted seams to the contact of an intense flame.

Experiments made with a double bottom, having talc interposed, showed that for an evaporative rate of 32 pounds the temperature of the plate exceeded 630 degrees, and that for an evaporative rate slightly greater the temperature exceeded 842 degrees, indicating that overheating was imminent. This is a clear proof of the danger of deposits in the vicinity of the furnace.

The heated surface was then covered with grease internally, and it was found its external surface had a much higher temperature than in the case of a clean plate; but when the intensity of the fire was increased some special facts were noticed.

The difference of temperature between internal and external surfaces is 90° above that of the clean plate, for an evaporative rate of 32 lbs., and more than 360° for an evaporative rate of 51 lbs., producing a dangerous degree of overheat in the latter case. In other experiments, even at moderate evaporative rates, not exceeding 35 lbs., the temperature of the external surface of the plate was 856°, greater than the melting point of zinc.

To determine the reason for these different results, experiments were made with tin vessels exposed to direct flame. It was observed that these vessels, when coated with grease on the interior and filled with water, became red hot in some cases, even with a moderate fire; and it was concluded that the nature of the grease modified the results. The following is a summary of the facts observed with different oils and greases:

Mineral oil, when applied thinly, produces no appreciable effect; but it causes overheating after being decomposed by heat. A chip soaked in mineral oil and applied to the plate causes overheating.

Linseed oil, even when very thinly applied, causes a rapid overheating of the plate at the moderate evaporative rates of from 21 to 25 lbs.

The same is true of *red lead putty*. If a ball of this material is flattened against the plate, the latter will become red hot even with a moderate fire.

Rapeseed oil acts in the same manner as linseed oil, but does not produce quite so rapid an effect.

Valvoline does not cause overheating except at a high evaporative rate, say 72 lbs.

Lard oil causes overheating, even when mixed with a considerable quantity of plumbago. If the plumbago is greatly in excess, the metal does not become red hot.

Tar, applied to a tinned or polished surface, becomes detached when the water boils. If applied to a rusty plate it adheres better, but does not cause overheating.

Mr. Hirsch draws the following conclusions from his experiments:

1. A sound and continuous sheet, in contact with water on one side, never acquires, however intense the fire may be, a temperature sufficiently high to sensibly decrease its strength.

2. The viscosity of the water, even when considerable, does not lessen its refrigerating action.

3. The transmission of heat is more or less affected by riveted seams, and such seams should not be exposed to an intense fire.

4. A diminution of thickness in a plate, caused by a flaw or crack, or a lack of close contact between two sheets at a seam, is a grave cause of danger, even with moderate fires.

The contact of the masonry setting even at a very high temperature is not dangerous if the plate is continuous and in contact with water on the other side.

6. Any grease or oil on the internal surfaces is a serious obstacle to the transmission of heat.

7. When the oil or grease is decomposable by heat, overheating is particularly to be feared. The organic oils, linseed, rapeseed, etc., appear to be more dangerous in this respect than the mineral oils.

MR. WILLIAM COWLES, MEMBER.—I exceedingly regret that I have not time at present to discuss in detail the timely and interesting paper of Assistant Engineer S. H. Leonard, U. S. N.

There are some points, however, which I would like to touch upon briefly.

The statement in regard to the trials of the *Thornycroft* boiler are not accompanied by any data in regard to calorimetic tests. In the absence of these, and in spite of the high standing of Prof. Kennedy, one may be permitted to doubt the efficiency of eighty-seven per cent. given.

I know that these figures were published in *Engineering*, but

with no more explanation in regard to the steam furnished than Mr. Leonard gives.

I believe there is entirely too much of just such bald statements in regard to boiler tests, and I think such statements should not be allowed to go unquestioned in the pages of the JOURNAL.

Mr. Leonard's account of his experience with small Herreshoff boilers is interesting and valuable, but it cannot apply to any great degree to the questions involved in large water-tube boilers for *cruisers* and *torpedo boats*.

In reference to the comparative table, I cannot see that the comparisons are fair in all respects.

A very important thing, the duration of the several tests, is not given.

It is hardly proper to take the cubic space as the space occupied by the boiler itself, because this leaves out in many cases the spaces about the boiler which it is impossible to utilize for other purposes, and which are virtually wasted by the boiler.

It seems to me that the proper space in a comparative table should be given as the space required for the boiler, the necessary passages, and clearances for accessibility and the necessary fire room required.

Another thing about the table: In the column marked "percent. moisture," were these percentages all obtained by calorimetic tests? It does not seem to me that this percentage should be constant, with greatly varying conditions of draft, as stated.

Mr. Leonard himself points out the incongruous nature of the table, which contains small boilers of four to nine square feet of grate surface, compared with large boilers of over fifty square feet of grate surface all in one furnace.

The duration of trial is a thing which might alter this table entirely.

A boiler might be capable of showing the very best of results on a test of two, four or six hours at natural or moderate drafts, whereas the same boiler, if run continuously for a longer period under the same or greater draft, might show entirely different results. Therefore, I wish to point out that, taken as a

whole without the strictures which I have made, the table is manifestly misleading and unfair.

I appreciate that there is comparatively little accurate information on this subject, and that Mr. Leonard has had to fill up his table with the data available, and not the data which we would all like to have.

This is a very important subject, and no doubt we shall hear more of it in the JOURNAL. At any rate, I am glad to see Mr. Leonard lead off and bring the matter up before the Society.

MR. MIERS CORYELL, ASSOCIATE.—I have read the paper on Tubulous Boilers with much interest, and regret that the limited time allowed for discussion will not permit of the preparation of such remarks as I would like to submit. I have made a special study of the Belleville boiler, and I consider that the statements in regard to it in this paper, while accurate enough for the case discussed, give a very unfair idea of the Belleville system. With the consent of the Council, I will be glad to prepare an article for the next issue of the JOURNAL, giving a full account of the boiler, with data of its use for large powers (8,000 to 10,000 I. H. P.,) on large war vessels and merchant steamers.

PASSED ASSISTANT ENGINEER R. S. GRIFFIN, U. S. NAVY.—It seems to me that in the comparison of different types of boilers, especially those intended for naval use, too much importance cannot be given considerations of weight and of space occupied; and as the table given by Mr. Leonard is based on an arbitrary consumption of coal per square foot of *grate*, I have prepared the accompanying figures with a view to showing in what important points the several boilers differ. The final figures are based on the assumption that, considerations of a practical nature being the same, the value of any boiler is directly proportional to

1. Pounds of combustible burned per square foot of heating surface per hour.
2. Pounds of water evaporated per pound of combustible.
3. Heating surface per cubic foot of space occupied.

and inversely proportional to

4. Weight per square foot of heating surface.

In other words, at the same rate of combustion per square foot

of heating surface, the value of the boilers is directly proportional to 2 and 3, and inversely proportional to 4.

The first factor takes into consideration the rate of combustion; the second, the efficiency of the heating surface; the third, the bulk of the boiler; the fourth, its weight.

Taking the boilers given by Mr. Leonard, arranging them in the order of their rates of combustion, giving to each its initial letter (using *w* for the small Ward boiler), and introducing the Thornycroft boiler of the *Ariete* given on page 183, vol. 1 of the JOURNAL, designating it by *Th*, we have—

	1 Combustible per sq. ft. H. S.	2 Evap. per lb. combustible.	3 H. S. per cu. ft.	4 Wt. per sq. ft. H. S.	5 $\frac{1\times2\times3}{4}$
w.	.159	10.77	3 413	13.2	.443
T.	.190	13 40	3.694	21.8	.431
H	.301	10.23	2.945	14.8	.613
w.	.323	10.01	3.413	13.2	.836
B.	.501	10.42	1.228	53.2	.120
Th.	.823	10.83	2.180	10.2	1.905
S.	.870	9.93	1.268	41.2	.266
H	.930	8.68	2.945	14.8	1.606
W.	1.122	8.44	3.391	12.3	2.615
T.	1.148	6.77	3.694	21.8	1.317
S.	1.415	9.06	1.268	41.2	.395
w.	1.427	7.01	3.413	13.2	2.586
L.	2.220	7.74	1.771	31.3	.973
L.	2.728	7.35	1.771	31.3	1.134

The product of 1 and 2 is, of course, the evaporation per square foot of heating surface; but as it is important to know the rate of combustion, the above form seems to cover all points.

The rate of combustion for the Thornycroft boiler is taken as that given by Prof. Kennedy, using the maximum rate, and allowing 5 per cent. for refuse. For the locomotive boiler 10 per cent. has been allowed.

In column 2 no deduction has been made for moisture.

The figures in column 5 are the result of multiplying those in columns 1, 2 and 3 together and dividing the product by those in column 4. This is based on the assumption that each factor is of equal importance. When considerations of bulk, or of weight, or of bulk and weight, are of secondary importance, the relative value of the figures in column 5 will be materially changed. Although those figures have no absolute value, they may, within

certain limits, be taken as representing the relative values of the different boilers when the rate of combustion and their bulk, or the rate of combustion and their heating surfaces are approximately equal. Thus, it is not unfair to compare the Scotch and the Thornycroft, the Herreshoff and the small Ward, and, by making some allowance for difference in rate of combustion, the Thornycroft, the large Ward, the Scotch and the locomotive. The Belleville, though approximately of the same size as all except the Thornycroft, suffers on account of its weight and bulk, notwithstanding the high efficiency of its heating surface, and would appear to better advantage if the bulk and weight factors were given smaller weight. On the other hand, by increasing the value of these factors, as would be necessary where economy of weight and space are of the first importance, all of the heavy boilers appear at greater disadvantage.

Of the small boilers, the Towne is too small for a strict comparison with either the small Ward or the Herreshoff, but the figures given are of sufficient value to show wherein the several types differ.

To determine the absolute value of any of these tubulous boilers it is, of course, necessary to consider the conditions laid down by the author of the paper under discussion.

A question was raised by Mr. Ward about the duration of the trials of the Thornycroft boilers tested by Prof. Kennedy. The accompanying table, the data of which are from a paper read November 19, 1889, by Mr. Thornycroft before the *Institution of Civil Engineers*, the proceedings of which were recently received, will throw additional light on those trials, which were made during the month of November, 1888:

Duration, hrs. and min	4–57	5–9	4–0	2–0
Atmospheric pressure, lbs	14.55	14.80	14.84	14.45
Steam pressure in boiler	181.8	171.2	149.4	180.5
Steam pressure in H. P. valve chest	22.7	79.2	120.7	168.4
Air pressure, ins	0.	0.27	0.49	2.00
Weight of coal, lbs	1,006.5	2,877.	3,575.	3,503.
Weight of ashes, lbs	233.5	197.	.....	192.
Weight of ashes put back on fire	233.5	170.	0.	192.
Coal burned per hour	203.3	559.	894.	1,751.

Grate surface, sq. ft.	26.2	30.	30.	26.2
Heating surface	1,837.	1,837.	1,837.	1,837.
Coal per sq. ft. grate	7.74	18.6	29.8	66.8
Feed water per hour	2,281.	5,852.	8,583.	15,554.
Temperature of feed, Fahr.	76.3	78.0	83.8	111.2
Temperature of steam	380.2	375.5	365.5	379.6
Evaporation from and at 212° (with ashes burned)	13.4	12.48	12.00	10.29
Temperature of chimney gases	421.	540.	610.	777.
Air pressure in chimneys	0.	0.03	0.12	0.40

No calorimetric measurements were made, but Prof. Kennedy maintains that it is quite unlikely that any priming occurred on the first trial, from the fact that the boiler was evaporating only one-seventh as much water as it did on the last one. Mr. Thornycroft, in replying to the discussion, says that when the boiler was worked very hard a little priming was, at times, evident, but that the water had been carried especially low in the separator *with a view to prevent it.* It appears highly probable that some water was carried over with the steam on the first trial, for it must be remembered that the boiler is, from its very construction, a *priming* boiler, and the rate of evaporation was so low that the engine had to be throttled down to keep its power down to the capacity of the boiler. Under such conditions it does not seem at all improbable that the engine was at times using more steam than the boiler was evaporating. This would certainly occur at the time of firing. Mr. Thornycroft says that when working at low power "the water was sent into the boiler much too rapidly, causing a fall in the steam pressure, and then, while the other tank was filling, there was a long pause when no water could be obtained."

In our service, priming of water tubular boilers in steam launches has frequently been reported; investigation usually developed the fact that the rate of combustion was low, the apparent evil having been remedied by increasing this rate, the priming at the maximum rate of combustion, if any existed, being imperceptible.

As to the water used per I. H. P. per hour by the engines, Prof. Kennedy calls attention to the low steam pressure in the

high-pressure valve chest, and to the fact that the I. H. P. is that of the main engine alone, while the water measured was that from all the engines; the auxiliaries in use were a circulating pump engine, a fan engine, and, except in the third trial, a donkey engine for feeding the boiler. The engine was a triple-expansion one, with cylinders 14, 20, and 31½ inches diameter by 16 inches stroke. The cylinders were jacketed.

In the discussion which followed the reading of the paper, attention was called not only to the absence of calorimetric measurements, but also to the fact that in trials of short duration, especially at low rates of combustion, the relative conditions of the fire at the beginning and at the end of the trial exercise an important influence on the recorded rate of evaporation. It may be of interest to note that, as a result of extended experiment, Mr. Thornycroft now uses brass tubes in his boiler.

Assistant Engineer Harold P. Norton, U. S. Navy.—The U. S. S. *Atlanta's* steam launch was built by the Herreshoff Manufacturing Co., the machinery consisting of a compound engine with cylinders 4 and 7 by 7 inches, and a square boiler size *F*, with five flats, and a grate surface of 7.73 square feet and 82.8 square feet of heating surface.

The boiler was very unsatisfactory, as it was constantly giving out and causing the steam launch to be laid up for repairs.

The leaks were nearly always in the joint between the ends of the tubes and the return bends. I think most of this trouble was due to the service the boat was used for, as it was very irregular, and with this type of boiler a sudden stoppage of the pumps when the fire is heavy means great danger of overheating the flats, and when the pumps are started again the water striking the hot tubes and bends causes sudden contraction. As the tubes are made of wrought and the bends of malleable iron, they do not contract equally.

This trouble was so great that everything that could be was done to prevent it. The machinery as fitted by the builders had only the pumps on the main engine, and an injector. The injector was so unreliable, on account of its construction and the water in the tanks being warm, that it was removed. As it was then

necessary to run the main engines to feed the boiler, an auxiliary pump, No. 000, Knowles, was fitted, but owing to the many leaks in the boiler it was necessary to run the pumps so constantly that it soon gave out, and was replaced by a pump two sizes larger. To try and protect the bends from the heat and keep their joints tight, the shelf supporting the bottom flat was made wider by an additional row of bricks on each side, and the bends were imbedded in fire clay; but this only afforded temporary relief, and the upper flats continued to give trouble. The repairs continued to be so constantly needed that to enable them to be made quickly the deck was cut and a hatch fitted so that the flats could be removed without disturbing the machinery, and the pipe connections and spare flats were kept on board ship that could be quickly used to replace the leaky ones. I do not think it possible to use a Herreshoff boiler successfully for any purpose where the engines are worked irregularly without any notice of when they are to be stopped or started, or how long they will be used or remain stopped.

The supply of feed water is so nearly equal to the steam used, that with spread fires it is absolutely necessary to keep some feed water always entering the boiler, and the trouble of starting a pump or injector the instant the main pumps are stopped, often causes the man in charge to neglect to do so, in hopes that the stop is only temporary, until the flats are hot and the mischief done. I have not said anything about the faults due to poor design, which made it very difficult to keep grate bars from burning out and to keep a bottom in the ash pan, as these were overcome by practically building a new boiler casing and were not due to the type of boiler.

ASSISTANT ENGINEER S. H. LEONARD.—The writer is pleased with the discussion called forth by the above paper, and has taken much interest in reading the same.

In regard to the vertical tubular boiler, alluded to by Mr. Manning, it seems to me that there would be difficulty in using it, even in the deepest draught vessels now in our naval service, for want of overhead room, unless the height of the boiler was considerably reduced; and would not this seriously impair its

efficiency? I hope Mr. Manning will soon find the opportunity to give us the additional information promised.

Mr. Loring was correct in his inference as to intruders in the "moisture column," they having crept in at the printing office, and having been removed in the subsequent proof reading.

Although an automatic feed may be "a device of the devil," I question whether some of his devices are not necessary evils. It was not my idea to have it *displace* "human intelligence," in the shape of a water-tender, but, as stated, to *assist* him. It should not be allowed to gain one's confidence to the extent that it would be neglected.

In making repairs to the Herreshoff coil, I did not find it necessary to destroy any of the pipes in a section excepting those defective. In case of a defective pipe in the middle of a section it was cut in two with hammer and cape chisel—the ends were carefully dug out of the return bends (if they could not be screwed out), so as not to injure the threads of the latter. The new length of pipe was then started by hand until the threads caught in their respective return bends, when the two adjacent bends at one end could be sufficiently separated to admit of applying a Stillson wrench to the end of the pipe. In case of a defective *return bend*, the two lengths of pipe entering it were cut out and two new lengths of pipe and a new return bend fitted and made up as before.

Mr. Ward's remarks are timely, and effectually refute the assertion, so often heard, that a tubulous boiler is always short-lived, and during its brief existence under a constant state of repair. Mr. Ward falls into error in obtaining the pounds of water per I. H. P. used by the main engine in the Thornycroft test, from the fact that the steam used by the *auxiliary engines* was charged to the main engine, thereby making the coal consumed per I. H. P. larger than it should be. Prof. Kennedy states that the donkey engine was very wasteful of steam.

I cannot agree with Mr. Cowles that the test by Prof. Kennedy, quoted by the writer, can be classed as a "bald statement."

The Thornycroft boiler has a ratio of heating to grate surface of about 60 to 1. The efficiency of 87 per cent. was obtained

under natural draft, and consequently slow combustion, 7.7 pounds of coal per square foot of grate. Under such circumstances it does not seem to me that there should be much foaming, notwithstanding the fact mentioned by Mr. Griffin in regard to some of our own steam launches. We are all, of course, familiar with the fact that, if the speed of the engine is suddenly increased beyond the rate of evaporation in the boiler at the time, foaming is sure to ensue. This, however, can manifestly not last very long, for either the rate of evaporation must be increased to suit the engine speed or the engine speed will drop till it corresponds with the rate of evaporation.

The trial of this boiler, which gave the 87 per cent. efficiency, lasted nearly five hours, so it seems to me impossible that the foaming, if any existed, could have been due to a disproportion between the engine capacity and the rate of evaporation.

The temperature of steam at 182 pounds, the pressure used, is 380 degrees, and the temperature of escaping gases was but 421 degrees, consequently the loss from escaping gases was very small. The following short table shows the way in which the heat of combustion was utilized by the boiler:

Heat expended in heating and evaporating feed water.....	86.8	per cent.
Heat expended in raising temperature of furnace gases.....	10.8	per cent.
Heat lost through the formation of carbonic oxide.....	0.5	per cent.
Heat lost through radiation and unaccounted for.....	1.9	
	100.00	

It seems to me more likely that the wetness of the steam could be accounted for by the facts just given above, viz.: the small difference between the temperature of the steam and of the escaping gases. If, as suggested by Mr. Griffin, the boiler naturally tends to foam, there would, under these circumstances, be no chance for the steam to be dried; while, at full power, there would be a difference of about 400° Fahr., or enough to give the steam some drying effect.

In this connection, by referring to the large table, it will be seen that the small Towne boiler, with a very small ratio of heating to grate surface, gave the high evaporation of 13.4 pounds of water per pound of combustible.

Having two of the Thornycroft boilers now in our naval service, I trust an opportunity will soon occur for an evaporative test.

In regard to the questions involved in the working of a tubulous boiler, it strikes me that they are very similar, whether the boiler is large or small.

In making the calculations for the space occupied by the boilers, the *actual* dimensions were given, as it was thought that they would be the more satisfactory, thus allowing the reader to use his own judgment as to what additional space would be required in each case. He will be aided in this by the cuts of the different boilers given. Considering the different arrangements in various cases, it would be somewhat difficult to say just how much room a given type of boiler should be charged with, without knowing the circumstances.

I wish to add, in explanation of the fact that my paper contained so little about the experiments by Prof. Kennedy, that the Proceedings of the Institution of Civil Engineers were not received until the 10th instant, or almost a month after the paper was in type.

I trust, in view of the discussion which has already been elicited, and the paper of Mr. Thornycroft in the Proceedings Civil Engineers, which is now available, that in the next number those of our Society who were prevented from joining in the discussion in this number will give us the benefit of their views.

XI.

MACHINERY OF THE TORPEDO BOAT *CUSHING*.

By Passed Assistant Engineer Stacy Potts, U. S. Navy.

During the month of March last, the torpedo boat *Cushing* was subjected to a series of trials in Narragansett Bay and at sea to determine principally her speed and manœuvering qualities, her power and economic properties being of secondary consideration, as long as the speed and sea worthiness were secured. As the following figures depend principally upon the power of the engines and the amount of coal consumed, and as no means were provided for taking indicator diagrams or of obtaining the correct amount of coal or water used, they are necessarily only approximate, but sufficiently near to give an idea of her performance. The power was obtained by comparison with another similar set of engines from which indicator diagrams had been taken, and the amount of coal burned estimated from the amount put on board previous to each run, and the amount remaining at the termination of the run.

The hull and machinery, with the exception of the boiler, were designed by Mr. Nathaniel Herreshoff, and built by the Herreshoff Manufacturing Co., of Bristol, R. I., under the inspection of Commander Geo. A. Converse, U. S. Navy.

The principal dimensions of the hull are as follows:

Length over all,	137.5 feet.
Extreme beam,	15.05 "
Draught,	5.2 "
Displacement,	105 tons.

She has a ram bow, overhanging stern, twin screws, and a partially balanced rudder.

The main engines consist of two sets of quadruple-expansion engines of the vertical, overhead-cylinder type, the low pressure area being divided into two, thus making five cylinders of $11\frac{1}{4}$, 16, $22\frac{1}{2}$, $22\frac{1}{2}$, $22\frac{1}{2}$ inches in diameter, respectively, by 15 inches

stroke of piston. They are connected by the usual rods to five cranks, which follow each other at an angle of 144°. This gives a very equal distribution of pressure, which showed itself in the very smooth manner in which the engines ran and the almost total absence of vibration.

It is worthy of remark here that no water pipes are fitted for cooling off bearings, nor (with one exception) was a drop of water used on any of them, the exception being on one occasion when dirt got into a bearing on one of the eccentric shafts situated beneath an open hatch, which was kept from excessive heating by laying cotton waste soaked in water upon it. Each cylinder has its own valve chest inboard, each provided with a double piston valve. The main pistons and valves are packed by small cast-iron rings, and not a drop of oil is used or can be placed in either the cylinders or chests, a practice always adhered to by the builders, and which worked well. The frames are of steel rods $1\frac{1}{2}$ inches diameter, braced diagonally, and form the cap bolts of the main bearings, which in turn are secured to a bed plate consisting of a single sheet of wrought-steel $\frac{3}{4}$ inch thick, with openings cut through it for the passage of the cranks. This bed plate is secured along its edges in a fore-and-aft direction to keelsons, also beneath the main bearings of the high pressure and the after low pressure cylinders, the intervening bearings having no support at all beneath, and during the highest speeds no signs of working or weakness were noticeable around this apparently weak part.

The valves are worked by cranks on a small shaft running parallel with the main shaft, and geared to it at the forward end by cut steel gear wheels; the reversing being done by partially rotating this counter shaft by hand by means of a lever and spiral feathers and sleeves situated in the forward bearing. The reversing is done easily, and is practically instantaneous.

The cross-heads are of phosphor bronze; this does away with all gibs, set screws, keys, etc.; they envelop a couple of bar slides, the ahead bar being cast hollow and filled with water before or during a run and the water allowed to evaporate through the top. The top half of the slides was always warm

Cushing's Propellers.
diam. 4.27 ft. Pitch (mean) Stbd 8.03
Pitch (mean) port 8.20 ft. dev. area 9.37
sq. ft. for each. True Screw.

from the radiated heat of the lower heads of the cylinders. All of the oil cups are kept filled with horse hair to prevent the oil from jumping out, and are fed through pipes leading to a main tank on each engine. The main engines do nothing but turn the screws, all of the pumps being independent.

There is one surface condenser containing 1,052 square feet of cooling surface; it lies low on the keel in the after end of the engine room, the tubes running fore and aft. The heads are conical, and continue down through the bottom of the vessel about 8 inches, forming a scoop for the circulating water to enter and discharge when the vessel is under way, the cooling water passing through the tubes once. The forward scoop is provided with a strainer, the after one without, the idea being that, when backing, any foreign substance that may enter the after scoop would be washed out when going ahead again. Situated in the forward head are vanes 13¾ inches in diameter, forming a centrifugal pump and driven by a single vertical engine 4 inches diameter by 4 inches stroke. This engine and pump are used when the vessel has no motion through the water. When running at a speed of about twenty knots, and steam is shut off the circulating engine, the engine and pump make about 100 revolutions per minute, by the motion of the scooped water passing through it.

There are three single-acting, vertical, single-trunk, bucket air pumps for each main engine; they are 10 inches in diameter by 5 inches stroke, and are placed alongside and above the condenser; they have no foot valves, the bucket and delivery valves being flat annular rings of composition ¼ inch thick. The pumps are worked from a cast-steel shaft, the cranks being 120° apart. On the same shaft are three vertical, single-acting plunger feed-pumps 2⅞ inches diameter by 5 inches stroke. Each set of air and feed pumps is driven by two simple vertical engines 3½ inches diameter by 5 inches stroke, and geared down 3.2 to 1. These engines are controlled by a small ball governor, and worked very well, the air and feed pumps making about 240 strokes per minute when running at maximum speed.

All of the auxiliary engines exhaust into the main condenser

when not under way, and when under way into the low pressure receivers; this increases the pressure there about one pound.

There are two boilers, one forward and the other abaft the engine compartment. They were built of domestic material by the Herreshoff Mfg. Co., from drawings furnished by Messrs. Thornycroft & Co., England. As their type is well known it is useless to describe them. They each contain 38.3 square feet of grate and 2375 square feet of heating surface, or a ratio of 1 to 60. They each weigh, empty, 9 tons, or 11 tons with water to the steaming level. The safety valves are set at 250 pounds, and the boilers have been tested to 500 pounds per square inch.

According to the instructions and drawings furnished by Thornycroft & Co., five zinc discs, 14 inches diameter by $\frac{1}{2}$ inch thick, were placed in the top drum; they were connected with each other by a copper wire and to the metal of the drum. In each of the lower drums there are four zinc bars $1\frac{3}{8}$ inches diameter by 5 feet long, suspended on bearing bars at each end. About one month previously to the first official trial the above distribution of zinc of the quality known as "La Salle" was placed in the boilers, the boat being tried occasionally by the builders. At the end of about three weeks the boilers were again opened and the zincs found to be in a generally disintegrated state, most of it appearing like sand or gravel upon the lower sheets of the drums. It was removed and a quality known as "Virginia" put in its place. Upon starting out upon the first official trial the forward boiler commenced to foam, which was evidently caused by dirty water, as it appeared cloudy in the glasses, and when the gauge cocks were tried it left a muddy streak down the front of the drum head. By pumping and blowing the water was thoroughly changed, and since then no trouble has been experienced from foaming. The dirty water was probably caused by not thoroughly washing the boiler out after removing the old zincs.

After all of the official trials were over, the boilers being under steam about three weeks, the after boiler was opened and examined and everything found to be in good condition, no signs of leaks, pitting or corrosion being noticeable. The zinc discs in the upper drum were intact and showed signs of a gradual wast-

ing away on the surfaces exposed to the water; several of the zinc bars in the lower drums were broken and lay upon the bottom sheets. This was caused by want of support in the middle of their lengths. About a quart of muddy dirt was found in each lower drum.

Steam can be raised from cold water in about half an hour, or from banked fires in about fifteen minutes, but twice that time is usually taken. There is an annular opening ½ inch wide leading from the fire room to the space between the smoke pipe and its casing, the original idea being to lead pipes to the casing from the several compartments to assist ventilation; the idea was not carried out, but the opening remains, and with this exception the fire rooms and adjoining bunkers are air-tight. Air is supplied to each fire room by a fan 36 inches diameter, secured to the athwartship bulkhead, and driven by a single vertical engine 4 inches diameter by 4 inches stroke, situated on the main engine-room side of the same bulkhead. No difficulty was experienced in maintaining 4 inches air pressure, the fans making about 800 revolutions per minute.

The ash-pit doors, as well as a couple of doors on the front casing of the boilers, open inward, and are hung a little above their center of gravity; with natural draught the bottom of the doors swing open about ¼ of an inch, and with 4 inches air pressure they hang almost horizonal. The doors mentioned above on the front casing are for the purpose of allowing air to circulate through the front and fire doors to keep down the temperature. In case of any serious leak or pressure within the fire box or ash-pit, the doors would close by the pressure against them. The fire doors are hung on an inclined shaft, with a counterbalance at the end, and are kept shut by a spring catch.

The steam pressure is entirely controlled by the throttle valve of the blowing engines, and the feed-water supply by the speed of the feed pumps; this, for both boilers, is attended to by one man in the engine room, who receives on an indicator signals from the fire rooms the state of the water level given by the firemen. The arrangement worked very well. There are two automatic glass water gauges and three gauge cocks on the

front head of the top drum. On several occasions the glasses broke, and their automatic closing mechanism worked perfectly.

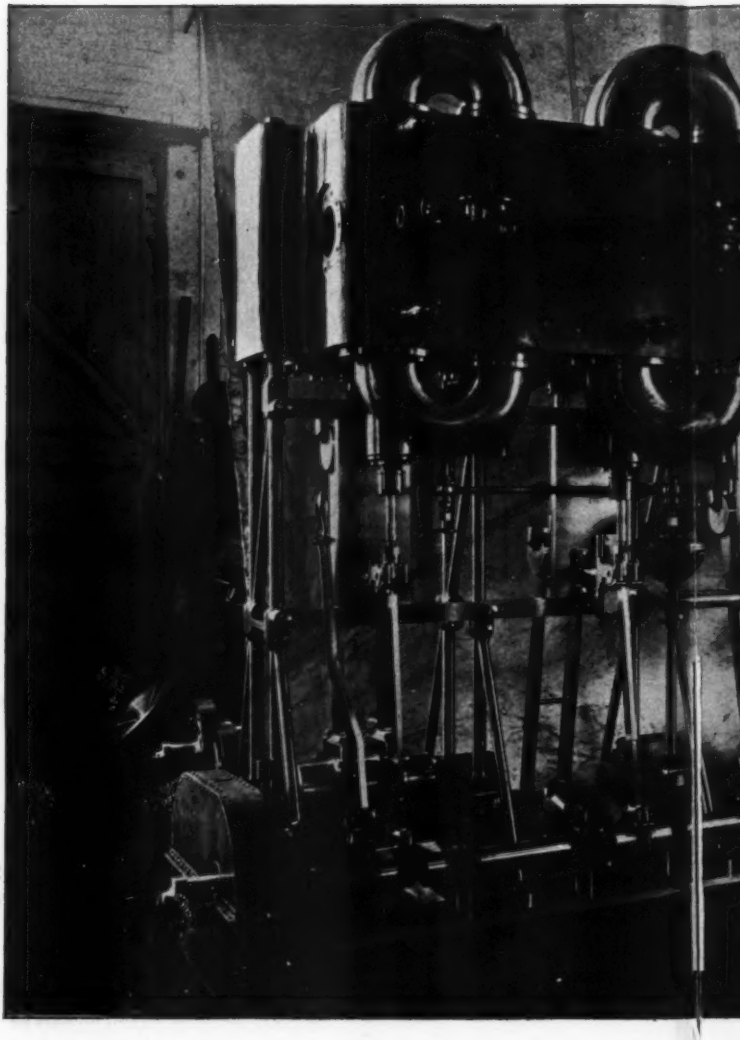
With closed hatches and the blowers running the temperature in the fire rooms is not 10° above the temperature on deck.

There is in each fire room a duplex auxiliary pump for all around purposes, and at the conclusion of the three-hour full speed run it was found that the reserve supply of fresh water kept in a tank beneath the forward fire room floor plates had been used up on account of the safety valves lifting frequently. An attempt was made to draw water from the sea with the after auxiliary pump, but it was found that it would not draw water until the speed of the boat was reduced from 20 to about 12 knots. The strainers on the end of the suction pipes projected slightly from the skin of the vessel.

During the maximum speed trial for three hours not the least difficulty was experienced in keeping 245 pounds of steam and burning about 45 pounds of bituminous coal per square foot of grate per hour. Two firemen were employed in each fire room, but one man in each could have done the work required.

After the fires are banked after each run, the exterior of the tubes are cleaned of soot, &c., by running the blowers fast and turning a jet of steam among the tubes, taking about one minute for the operation. There is also an ejector fitted with a water spray on the front of each boiler, and which can be used to quench the fires in case of necessity.

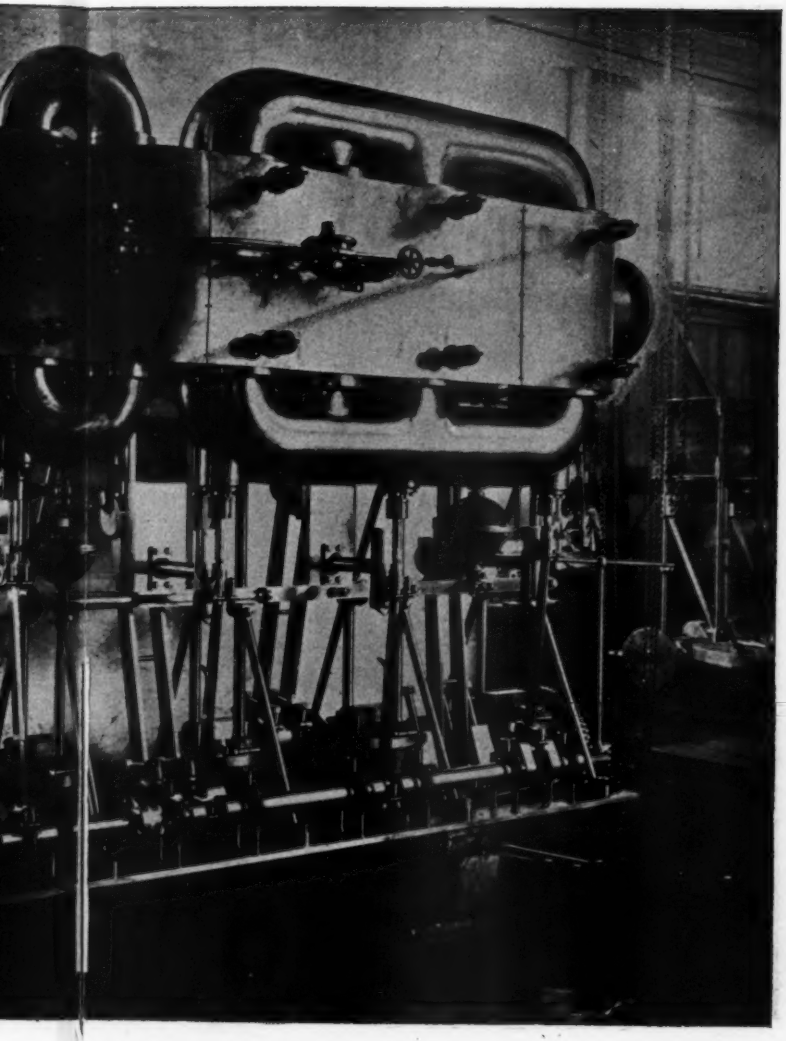
There are a couple of points in connection with the design of this particular type of boiler not generally understood: 1st, the top plates of the drums where the tubes are secured are $\frac{5}{8}$-inch thick, and the lower plates $\frac{1}{4}$ and $\frac{3}{8}$, the edges of the top plates being planed down before bending to the decreased thickness to form the joint. Thornycroft & Co. specified that the longitudinal seams were to be double riveted, but in the *Cushing's* boilers it was decided to weld the seams of the drums, as it made a stronger joint. The drums were made at the Continental Iron Works; 2d, the last two outside rows of tubes are $1\frac{1}{4}$ inches diameter, all of the remainder being $1\frac{1}{8}$ inches. The first two rows come together about 18 inches above the grate, lie side by side, and



BELL LITHO. CO.

STARBOARD ENGINE OF U. S. T

Diameters of Cylinders, 11¼″; 16″; 22″; 22″; 22



E OF U. S. TORPEDO BOAT CUSHING.

22″; 22″; 22″. Stroke, 15″. Steam Pressure, 250 lbs.

WASHINGTON, D. C.

almost touch each other from this point up to the center of the fire box, thus forming an almost solid crown sheet, protecting the bottom sheets of the top drum from the flame and gases, and directing them in and around the interior tubes. The same way with the two outside rows of larger diameter, forming an almost solid water wall or sides of the boiler.

The tubes are expanded by the ordinary roller expander, the lower drums being 14 inches diameter, large enough for a boy to enter. Out of about 1,600 tubes expanded 11 were found to require re-expanding. When a tube leaks or gives out the drums have to be entered and a special screw plug with a tapered washer inserted in each end of the defective tube. This process can be kept up until half of the tubes are plugged, as the boiler would then have a ratio of 30 to 1 heating to grate surface.

There is no doubt that clean fresh water only can be used, as with dirty water or a mixture of salt the boilers will foam. With reasonable care and attention it is believed that the boilers will last as long as the hull of the boat, the deterioration likely to take place first being pitting or corrosion in the steam space and around the water line in the top drum.

	22.5 Knots.	20 Knots.	15 Knots.
Duration of run	3 *hours.*	1 *hour.*	2 *hours.*
Steam pressure in boilers, lbs	245	150	110
Steam pressure in 1st rec., lbs	100	59	...
Steam pressure in 2d rec., lbs	40	19	...
Steam pressure in 3d rec., lbs	5	5	...
Vacuum, inches	24	24	24
Revolutions main engines per minute	370	300	210
Revolutions air pumps per minute	122	134	100
Revolutions circulating pumps per minute	100	100	...
Revolutions forward blower per minute	825	330	400
Revolutions after blower per minute	500	436	...
Air pressure in forward fire room, inches	3	·375	·5
Air pressure in after fire room, inches	2.5	·5	...
I. H. P. main engines	1,720	840	430
Coal per hour, bituminous	3,446	1,800	730
Grate surface, square feet	76.6	76.6	38.3
Coal per square foot of grate per hour	45	23	19
Coal per I. H. P. per hour	2	2.1	1.7

The above figures relating to power and coal consumption,

are approximations only, as mentioned at the beginning of this article; as the work done in the fire rooms was extremely light, it is reasonable to believe that she is a very economical boat, and it is hoped the Government will subject her to more tests, to determine more accurately her power and coal consumption at different speeds.

The accompanying illustration is from a photograph of one of the *Cushing's* engines as erected in the builder's shops.

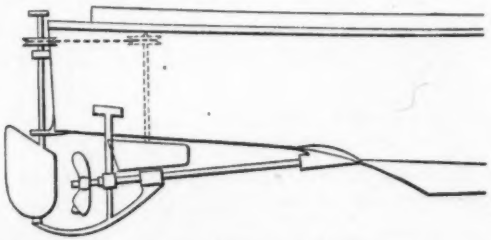
XII.

THE WHITE PATENT STEAM "TURNABOUT" LIFE LAUNCH.

By Assistant Engineer F. M. Bennett, U. S. Navy.

A description of a steam cutter built by Mr. J. S. White, of Cowes, Isle of Wight, for the U. S. S. *Enterprise*.

The peculiarity of this boat is the steering arrangement, which constitutes the "turnabout" feature of the system, and which makes the boat very obedient to the movements of the rudders. The use of two rudders, one forward and the other aft of the screw, and the cutting away of the keel aft for about one-third of the length of the boat, are the features peculiar to this system



and which may be readily understood by reference to the accompanying sketch. The simultaneous action of the rudders is ef-

fected by means of rods connecting yokes on the two rudder heads. This system is applied to torpedo boats and steam yachts, as well as to small steam launches.

The launch built for the *Enterprise* is 32 feet long, 7 feet beam and 3 feet 8 inches deep; weight, about 3 tons; indicated horse power, about 24; speed, about 8½ knots per hour. The hull is of two thicknesses of mahogany, the inside skin worked diagonally and the outer one fore-and-aft, with water-proof material between. Air compartments are fitted at each end, and extend fore and aft along the sides, reaching to the gunwale. These compartments are constructed of two thicknesses of mahogany and teak, with water-proof material between, and are designed to have sufficient buoyancy to float the machinery and crew should the boat be filled by a sea.

The boat is steered by a wheel forward and by a tiller aft.

A metal fresh-water tank, holding 37 gallons, is fitted for auxiliary supply to the boiler.

An ejector for clearing the bilge and a hand pump for the same purpose are supplied.

Folding canvas hoods are fitted over the stern benches and over the coxswain's box forward.

The usual boat gear, oars, boat-hooks, lumber crutches, fenders, etc., are supplied.

The machinery for this cutter was built by G. E. Bellis & Co., of Birmingham, a firm famous in England for excellent workmanship. Following is the contract specification for machinery:

Engine.—Of the compound surface type, with cranks at right angles, the cylinders being of strong, close-grained cast iron, supported on steel columns, with diameters of 4¾ and 8¼ inches respectively, and stroke of 5 inches. To be fitted with gun metal glands and bushes throughout.

Pistons.—With Ramsbottom rings of special metal.

Slides and gear.—Slides of the flat type, worked by link motion of forged steel and eccentric rods, and well arranged reversing gear.

Shafting.—Stern shaft of rolled naval brass, carried in brass tube with lignumvitae bearings.

Motion work.—Connecting, piston, slide and eccentric rods, together with all other working rods, of forged steel. All main bearings, connecting rod and other working brasses to be of the best gun metal, to be adjustable throughout, and fitted with double nuts and guard pins, as necessary.

Propeller.—Of gun metal, three bladed.

Feed pumps.—Two in number, of gun metal, and driven by crank shaft.

Boiler.—Of the ordinary launch type; the plates of open-hearth steel; the furnace plates of specially soft quality, to withstand the effects of the furnace temperature. The boiler stayed throughout, and capable of withstanding a working pressure of 130 pounds per square inch. Boiler fitted with brass tubes, ferruled at the fire box end, and mounted with main and auxiliary stop valves, two water gauges, two pressure gauges, two test cocks, two feed valves, two spring safety valves and blow-out cock. Area of fire grate, 3.8 square feet. Area of tube surface, 76 square feet. All pipes of the best selected copper.

Air pump.—$3\frac{3}{4}$ inches diameter $\times$ $1\frac{1}{2}$-inch stroke. To be driven off main engine shaft by an eccentric; to be entirely of gun metal, equal and similar in all respects to those fitted in launches of this size built by me for H. M. and foreign navies.

Condenser.—To be formed by a special arrangement of copper tubes outside the boat, in such a position that the launch can take the ground without injury to same.

Tests.—The boiler and high pressure cylinder tested by water pressure to double the working pressure, or 260 pounds per square inch. The low pressure cylinder and receiver to 130 lbs. per square inch.

A preliminary trial of this cutter took place November 15, 1889, over the measured course in Spithead Channel, the data of which is given in table A. The conditions at this time were very favorable, the sea being smooth and the water deep. Unfortunately no diagrams were taken from the engine, as the trial was an unofficial one. On the day set for the official trial there was a heavy sea running, rendering it impracticable to take a

boat of this size upon the course off Norris Castle, and the trial had therefore to be conducted in shallow water in the Medina river, where there is a half-knot course laid down with suitable range marks and steering points. The results of this trial are given in table B, from which it will be seen that the contract speed and horse power were both exceeded, although the results were not so satisfactory as those of the unofficial trial.

The contract price for this steam launch complete was 590 pounds sterling. For a steam launch of the same size and power, similar in all other respects to this one, but without the "turn-about" feature, the builders bid 525 pounds.

TABLE A, GIVING DATA OF UNOFFICIAL SPEED TRIAL OVER MEASURED ONE-HALF KNOT OFF NORRIS CASTLE, ISLE OF WIGHT, IN SMOOTH, DEEP WATER, NOVEMBER 15, 1889.

(Odd-numbered runs, with the tide. Even-numbered runs, against the tide.)

Number of runs.	Steam in boiler.	Vacuum.	Revolutions.	Observed time on ½ knot.	Speed due to time.	Mean speeds.
1	52	25	350	3′–41″	8.14	7.57
2	55	25	350	4′–17″	7.00	
3	100	25	440	3′–19″	9.04	8.50
4	100	25	440	3′–46″	7.96	
5	120	24	480	3′–11″	9.42	8.97
6	122	24	480	3′–31″	8.53	

TABLE B, GIVING DATA OF OFFICIAL SPEED TRIAL OVER MEASURED ONE-HALF KNOT IN MEDINA RIVER, ISLE OF WIGHT, IN SMOOTH, SHALLOW WATER, WITHOUT TIDE OR CURRENT. WEIGHTS ON BOARD: COAL, 3 CWT.; FRESH WATER, ¼ CWT.; SUNDRIES, 1 CWT.; AND 8 PEOPLE.

Number of runs.	Steam in boiler.	Vacuum.	Number of revolutions.	Average revs. per minute.	Observed time on ½ knot.	Speed due to time.	Mean speed.	I. H. P. from diagrams.
1	50	26	1,417	336	4′–13″	7.11	7.245	8.497
2	52	26	1,402	345	4′–04″	7.38		
3	78	26	1,417	365	3′–53″	7.73	7.795	11.79
4	77	26	1,405	368	3′–49″	7.86		
5	101	25	1,590	433	3′–40″	8.174	8.174	19.18
6	101	25	1,599	436	3′–40″	8.174		
7	130	24	1,664	489	3′–24″	8.82	8.78	26.94
8	130	24	1,689	492	3′–26″	8.74		
9	131	24	1,654	486	3′–24″	8.82	8.76	
10	132	24	1,692	490	3′–27″	8.70		
11	131	24	1,655	491	3′–22″	8.91	8.805	
12	131	24	1,681	487	3′–27″	8.70		

Indicator diagrams were taken under different steam pressures and different speeds during the trial with the following results:

Number of run, .	1	3	5	7
Mean pressure, H. P.,	32.55	44.4	56.0	71.5
Mean pressure, L. P.,	8.25	9.63	14.8	17.8
I. H. P., H. P., . .	4.782	7.086	10.601	15.285
I. H. P., L. P., . .	3.715	4.703	8.583	11.655
I. H. P., total, . .	8.497	11.789	19.184	26.940

The diagrams were taken with a Dark indicator, a very small, light instrument adapted to small, high speed engines.

XIII.

IS THE PATENT LOG MALIGNED?

By Chief Engineer F. G. McKean, U. S. Navy.

The matter of accurately recording the speed of our vessels on their trial trips is abundantly shown by the excellent paper of Messrs. McFarland and Norton, in the February issue of the Journal, to have become of the highest importance from many points of view; but it seems to follow from that essay that if the alleged errors of the patent log could be eliminated, even partially, there would be little left to desire.

The object of the following remarks is to suggest that until some radical improvement is made in the patent log, or that instrument is altogether superseded, it is our main stay; that we treat it without sufficient consideration and then find fault with it, instead of giving it a fair chance and using it to better purpose.

Mr. Mattice notes, what all observers must have seen, that the log gear will occasionally cease registering, and then at irregular moments spin around very rapidly. Messrs. McFarland and Norton observe that not only will two logs differ from each other, but the same log will differ from itself under repeated observations in apparently similar circumstances.

The unreliability of the instrument—and which might involve thousands of dollars, according to the exact instant at which its readings are taken—is doubtless due to the following causes: the flexibility of the connection between the propeller of the log and the registering gear; the great length of that connecting line—considered necessary in order to avoid currents formed by (*a*) revolving eddies from the ship's propeller; (*b*) the backward thrust of water from the propeller; and (*c*) the following water set in motion by the friction of the hull.

Discrepancies between two different logs and in the same log

at different times, are probably to be expected from the facts that: 1. With a log towed from each quarter the two instruments are affected differently in a long and crooked course like the one mentioned, of the *Dimock* between New York and Boston, without compensatory crookedness in the other general direction; (when carried to the *n*th this action might be expected to reach its maximum on a turning trial, when we would anticipate that the log carried on the quarter furthest from the imaginary center of the turning course would record more revolutions than its fellow on the inside track). 2. The log on one side of the ship may be expected to register a little differently from that on the other, according as the water is thrown by the ship's (single) propeller toward one side or drawn from the other. (The length of the line will nullify this in degree, but can hardly be expected to eliminate it altogether, especially in a fast ship.) 3. The momentary difference in the record of a log from its own former record, as regards either intervals of time or space, might be due to (*a*) the greater or less swerving of the vessel from the straight course (and to which Mr. Baird has called attention, either by unintentional bad steering or by purposed changes of course, avoidance of obstructions, etc.—swinging the log into or out of the eddies from the propeller and hull a greater or less number of times between different observations; (*b*) the action of a following or opposing tide in such a course as the one mentioned; (*c*) the assistance or retardation, often unnoticeable at the moment, due to stray puffs of wind: and (*d*) the almost impossibility of deciding, even on two consecutive runs, the exact instant when a ship "passes" some lighthouse or point; suppose there are no objects to range with the lighthouse or point, then the man of sanguine temperament is apt to say the ship has passed or rounded the landmark before she has really done so, while the conscientious man will be careful not to call "Time!" until after she has passed; but suppose there are range marks, then the ship will not, on two consecutive days, steam in exactly the same channel (understood in the sense of path), and whether she is a hundred yards outside or inside, yesterday's or to-morrow's course may make a decided

apparent difference in the record of the same log between the same points, according to the nature of the range marks, the absence or presence of sunshine, and other reasons for momentary dullness or distinctness of the ranges. In short, there is endless room for personal and other equations—all of which are ascribed to the log.

We must therefore, it would appear, look for the solution of this part of the problem in a modification of the method of connecting the log propeller with its gear, and in the simultaneous use of a greater number of such improved logs, if it be granted that the suggestion is an improvement.

In place of a flexible and long tow-line, then, let us have a metal rod just long enough to permit the recording gear to be a few inches instead of many feet above the water-level, so that, torsion of the rod neglected, each revolution of the fan will be recorded when made, and not by erratic accumulations of back work being rushed through semi-occasionally. Next swing out the lower booms on both sides, well secured by their lifts and braces, and from them suspend four or more firm platforms, which may be boatswain's chairs or crow's nests according as the observer is a Spartan or a Sybarite, and from which platforms may be read the knots and tenths recorded by the log index secured to the structure a few inches above the water. Under these circumstances the flexibility of the connections will be practically *nil*, the hull currents will be eliminated if the logs be attached sufficiently far from the ship's side, and the propeller eddies will cease from troubling.

Upon one other point the writer agrees with Mr. Mattice, and evidently Mr. Isherwood also, that the permissible force 4 of the wind is much too high for a trial nominally uninfluenced by wind; and if that figure be allowable, the ship may be expected to roll and be further influenced by waves; in which case some kind of receptacle will have to be provided to keep the observer's notes safe and dry. We lay no stress upon the probable fate of the observer himself, as "promotion 's very slow."

Lastly, if the changes suggested in the logs themselves and the method of towing them be deemed improvements, the crook-

edness of the course steered on a measured mile or in short distances may perhaps be allowed for by observers on deck, who can plot the course from their observations of the wake and make up for the extra distance due to that cause.

SHIPS.

UNITED STATES.—*Cruiser No. 6.*—This vessel which was advertised March 7, 1890, and for building which proposals will be opened June 10, is a protected cruiser of the following dimensions:

Length on water line, ...	330 feet.
Breadth, extreme, ...	53 "
Draught, mean, ...	21½ "
Displacement at above draught, . .	5,500 tons.

She is designed for a minimum speed of 20 knots, with 13,500 I. H. P.

Along the machinery space the protective deck is $4\frac{3}{4}$ inches thick on the slope and 2 inches on the flat; forward and aft of this it is 3 inches on the slope and 2 on the flat. In addition to this, there is a belt of woodite extending the entire length of the vessel.

There are two sets of vertical triple-expansion engines, in separate water-tight compartments, separated from each other by a central longitudinal bulkhead. The cylinders are 42, 59 and 92 inches diameter by 42 inches stroke, and the revolutions at maximum power are intended to be 128. There are six boilers, in four water-tight compartments; two of them are single and four double-ended, with four and eight furnaces respectively. All of them are 15 feet 3 inches diameter, the single-ended ones 10 feet 11 inches long and the double-ended ones 21 feet 3 inches. The grate and heating surfaces are respectively 824 and 28,298 square feet.

The armament comprises two 8-inch rifles, ten 4-inch rapid-fire guns, eight 6-pdrs. and six 3-pdrs. The vessel has two masts with double military tops.

Armored Cruiser No. 2.—On the 7th of March the Department issued a circular embodying the principal characteristics of this vessel with a view to getting builders to submit their own designs.

The following are the principal dimensions of the vessel designed by the Department:

Length on water-line,	380 feet.
Breadth, extreme,	64 feet 2¼ inches.
Draught, mean,	24 feet.
Displacement at above draught,	8,150 tons.
Immersed midship section,	1,360 square feet.

The estimated speed is 20 knots with 16,000 I. H. P.

Protection is afforded by a protective deck 6 inches thick on the slope and 3 inches in the center, a belt of woodite or other water-excluding material being fitted as in *Cruiser No. 6.*

There are four sets of triple-expansion engines in two watertight compartments, two sets of engines operating each shaft, disconnecting couplings being provided, so that at low speed the after engines only need be used. The cylinders are 32, 46 and 70 inches diameter by 42 inches stroke, and are supported on cast-steel columns resting on cast-steel bed plates. There are six double-ended and two single-ended boilers; the double-ended boilers are 15 feet 3 inches diameter and 21 feet 3 inches long, and contain 987 square feet of grate and 31,190 of heating surface. The single-ended boilers are 10 feet diameter, 8 feet 6 inches long, and contain 64 square feet of grate and 3,914 of heating surface.

The battery comprises six 8-inch and twelve 4-inch rifles, besides a number of machine guns.

Like *Cruiser No. 6*, she has two masts, with double military tops.

Philadelphia.—A preliminary contractors' trial was made May 7, during which, for a short period, the revolutions were 115; but owing to defects in the blowing engines, the main engines could not be run at full power for any length of time.

Vesuvius.—On the 10th of May, this vessel had a trial of eighteen minutes' duration for the purpose of determining the

I. H. P. of her engines during that period. The following are the mean results:

Steam pressure in boilers, per gauge, .	158 pounds.
" " 1st receiver, abs., . .	75 pounds.
" " 2d receiver, abs., .	28 pounds.
Vacuum, ...	24½ inches.
Revolutions, starboard, ...	267.78
" port, ...	270

The I. H. P. has not yet been computed, but will probably be 3,400 to 3,500.

The grate and heating surfaces of the boilers are respectively 195 and 8,981 square feet, and the cooling surface in condenser 4,518 square feet. The screws are three-bladed, 7 feet 9 inches diameter and 9 feet 4½ inches pitch, and have an area of 15.9 square feet each.

ENGLAND.—*Barracouta.*—A sheathed, third-class cruiser of the following dimensions: Length, 220 feet; beam, 35; draught, 14; displacement, 1,580 tons.

She has twin-screw triple-expansion engines, with cylinders 21, 31 and 45 inches diameter, by 24 inches stroke, designed for 1,900 I. H. P. with natural, and 3,000 with forced draft. The boilers, two in number, placed in separate water-tight compartments and working at a pressure of 155 pounds, are cylindrical, double-ended, 10 feet 9¼ inches diameter and 17 feet 6 inches long. At each end of each boiler there are two 37-inch furnaces which discharge into a common combustion chamber, which is divided to about the top of the lower row of tubes by two walls, one running across the chamber and the other longitudinally, dividing the chamber into four compartments. The distance of the top of the wall from the top of the combustion chamber is 30 inches. The grates are 7 feet 10½ inches long, the total grate surface being 195, and the total heating surface 5,230 square feet. There is one 6-foot fan in each boiler room for maintaining the necessary air pressure, the entire compartment being put under pressure.

She went out for a trial on the 30th of January, but owing to an accident to the steering engine the trial was postponed until

February 6, on which day a joint in H. P. cylinder leaked, necessitating a delay of another day. On the 7th, after having been under way about three-quarters of an hour, a serious accident occurred, occasioned by a rush of gas and flame from the ash-pits of the port boiler, which resulted in the death of two men and the injury of nine others.

At the time of the accident there was an air pressure of from $\frac{3}{8}$ to $\frac{1}{2}$ inch of water in the fire room, the steam pressure was about 153 pounds, and the revolutions of the engines 174, the engines at the time developing about 2,200 I. H. P.

The cause of the catastrophe has been the subject of a prolonged inquiry and of much conjecture, the principal causes assigned being low water and back draft. The low water theory appears to have the greater number of adherents, and is borne out by the appearance of the combustion chamber. On the top, forty-five out of seventy stays were leaking, on the port side twelve, and on the starboard fourteen. In the after tube sheet one of the braces between the nests of tubes was leaking, and in the forward one two; nineteen stay and eighteen plain tubes were leaking on the right-hand side, and twenty-one stay and sixteen plain tubes on the left side. In the forward tube sheet the leaky stay tubes numbered seventeen on the right side and twenty-two on the left; the number of plain tubes twenty-five and forty-one. The general appearance of the combustion chamber was indicative of overheating. Against the low water theory it is urged that a strong feed was on at the time of the accident, and that immediately after gas ceased to issue from the ash-pits water was showing in the gauge glass.

The "back draft" theory is based on the fact that the smoke-pipes, one for each boiler, are very short, and on the assumption that the fires were green and heavy, and that sufficient air for combustion was not being supplied; on opening a fire door the gas ignited, increasing in volume, forced itself out of the furnaces, and thus induced a draft down the smoke-pipe. This theory does not, however, account for the wrecked appearance of the combustion chamber.

It may be added that the hypothesis is also advanced that

there was a greater air-pressure in the other fire room, and that this caused the outrush of flame and gases. This assumes that the fire rooms at opposite ends are separate, but in fact they communicate, so that the air pressure must be the same in both.

The boilers are identical with those of the *Barrosa*, a sister vessel, which has had satisfactory trials.

Blanche.—A sister vessel to the *Barracouta*, had an eight-hour natural draft trial about the 20th of March, with the following results: Steam, 143; vacuum, 25.7; revolutions, 167.8; I. H. P., 1,832; speed, 14.75. A forced draft trial was attempted March 27, but had to be abandoned on account of leaky tubes. She had another trial March 31, with similar results.

Iris.—A recent trial of this vessel resulted in a speed of 17 knots with 6,658 I. H. P., the engines making 89½ revolutions. One of the *Mercury* gave only 16¼ knots.

Sharpshooter class.—After the repeated failures of this vessel to run a successful trial, another of the class, the *Seagull*, was tried in December, but the trial was of short duration, owing to the excessive vibration of the hull. The results with 2.3 inches air pressure were: Revolutions, 245; I. H. P., 3,033. It was then determined to strengthen the hulls of the others, the *Sheldrake*, *Skipjack*, *Spanker* and *Speedwell*, and to subject one of them to exhaustive trials in order to determine how much speed and power might be expected from them without injury to the boilers.

The *Speedwell* was selected for the purpose, and on the 4th of February attempted to keep up 3,500 I. H. P., but after running for nearly three hours with 1½ inches air pressure, the trial was stopped on account of leaky tubes. She had another trial on the 27th of February, this time running for three hours, making 3,584 I. H. P. and 19 knots, the revolutions being 257 and the steam pressure 134. Her smoke-pipes are to be made six feet longer, and another attempt made to approach 4,500 I. H. P., for which they were designed. The general impression seems to be that 3,500 I. H. P. is as much as can be got out of them.

On the 18th of March the *Sheldrake* made 16 knots with natural draft.

Undaunted.—Belted cruiser, sister ship to the *Orlando*, had a three-hours' trial on the 28th of February, with the following results; steam, 117; revolutions, 106.85; vacuum, 27; speed, 17.08; I. H. P., 5,739.

Widgeon.—The following are the results of the trials of this gunboat of the *Lapwing* class (described on page 260 of Vol. I):

Natural draft: Speed, 12.5; I. H. P., 854; coal per I. H. P., 2 pounds.

Forced draft: Revolutions, 192.86; vacuum, 23; speed, 13.5; I. H. P., 1,259; coal per I. H. P., 1.82 pounds; air pressure, 1½ inches. The mean pressures in the cylinders were 51.6, 24.8 and 12.68, and the corresponding I. H. P. 379, 409 and 471.

FRANCE.—The French navy is soon to construct three armored vessels of about 6,500 tons in private ship yards. One will be built at the Forges et Chantiers de la Méditerranée, to be called the *Bouvines;* the other two, the *Valmy* and the *Jemmapes*, will be built at the Chantiers et Ateliers de la Loire. These vessels are a modification of the *Furieux*. The principal dimensions are as follows: Length between perpendiculars, 283.8 feet; beam, 56.36 feet; mean draught, 22 feet; displacement, 6,485 tons; immersed midship section, 1,130 square feet. The engines will be horizontal and triple-expansion, driving twin screws. There will be sixteen tubulous boilers of the d'Allest pattern working at a pressure of 215 lbs. The I. H. P. under natural draft assisted by air jets in the smoke-pipe or ash-pits is expected to be about 7,400; and, under forced draft, the same power is expected with three-fourths of the boilers. The side armor will be 18.1 inches thick of "compound plates" or hammered steel. The main battery consists of two 34-centimetre (13.4″) guns, and the secondary battery of four 10-centimetre (3.94″) and four 47-mm. (1.85″) rapid-fire guns, and thirteen revolving cannon of 37 mm. (1.46″). There are also two athwartship torpedo tubes.

Four armored cruisers of the second class will be under construction before long. The *Charner* is now building at Rochefort, and the *Bruix* will be commenced there in 1891. Two

others will be built in private yards, the *Latouche-Treville* at the Forges et Chantiers de la Méditerranée, and the *Chanzy* at the Chantiers de la Gironde. These vessels have the following dimensions: Length between perpendiculars, 347.7 feet; beam, 45.93 feet; mean draft, 19.16 feet; displacement, 4,670 tons; immersed midship section, 720.6 square feet.

The engines are twin-screw triple-expansion and horizontal. There will be sixteen Belleville boilers. The I. H. P. under natural draft is expected to be 7,300, and under forced draft by air jets in the smoke-pipes or ash-pits 8,190. Special provision is made in these vessels to protect them against mélinite shells, and a belt of cellulose fibre is fitted. They will have two military masts. The battery consists of two 19-cm. (7.48″) and six 14-cm. (5.5″) guns in barbette towers; four 65-mm. (2.56″) and four 47-mm. rapid-fire guns, and six 37-mm. revolving cannon. There are five torpedo tubes, two forward, one at the stern, and two athwartship.

Vautour.—The final trial of this torpedo vessel, which was launched in 1886, has just been completed. The speed was 17.05 knots, and the I. H. P. 3,391. She is 216 feet long, 29⅙ feet beam, and 14 feet draught, with a displacement of 1,272 tons. She was designed for 18 knots, on 3,200 I. H. P.

GERMANY.—*Meteor.*—A dispatch vessel of this name was launched at Kiel on the 20th of January. She is 262½ feet long, 31¼ beam, 11⅛ deep, with a displacement of 905 tons, and is expected to make about 22 knots, with 5,000 I. H. P.

ITALY.—*Fieramosca.*—The trials of this protected cruiser, built by Orlando Brothers, Leghorn, were recently completed with satisfactory results. She made 15.6 knots with natural draft, and 17.5 with forced draft, and on a subsequent trial 18.6 knots. She is 290 feet long, 43 feet 5 inches beam, and has a displacement of 3,745 tons, and was designed for 7,500 I. H. P.

RUSSIA.—*Sinope.*—A trial of this battle-ship was recently made, during which a speed of 17¼ knots is reported. The trial was not altogether satisfactory, owing to some defects in the machinery. She is 339 feet long, 69 feet beam, and 26½ feet draught, the displacement being 10,180 tons.

Oriel (or *Orel*).—A vessel of this name for the Russian Volunteer Fleet was recently built and engined by Messrs. Hawthorn, Leslie & Co., and was tried on the 5th of March. She is a twin-screw vessel 452 feet long and 48 feet beam, and was in complete cruising condition with all weights and stores and 2,000 tons of cargo on board. The mean of two runs over a 9.6-knot course gave a speed of 19.37 knots, with 97.7 revolutions and 9,934 I. H. P. Subsequently, she made a six-hours' run at sea, during which the average revolutions were 96.4 and the I. H. P. 9,098.

The engines are vertical triple-expansion, with cylinders 34, 54 and 85 inches diameter by 51 inches stroke. Steam is furnished by four boilers 15 feet diameter and 18 feet long, containing 615 square feet of grate and 17,204 of heating surface.

DENMARK.—*Geiser*, a cruiser building at Copenhagen, is to be supplied with eight Thornycroft boilers, aggregating upwards of 5,000 I. H. P.

CHILI.—*Almirante Lynch.*—A torpedo gunboat similar to the *Sharpshooter* class of the British navy, was launched by Laird Brothers, Birkenhead, England. She is 240 feet long over all, 27 feet beam, and 8 feet 3 inches draught, with a displacement of 735 tons. The contemplated speed is 21 knots, with 4,500 I. H. P. The boilers are of the wet-bottom locomotive type. A sister vessel, the *Almirante Condel*, is building by the same firm.

ARGENTINE REPUBLIC.—Laird Brothers are building a similar vessel to the above for the Argentine Republic. She is 210 feet over all, 25 feet beam, about 8 feet draught, and 615 tons displacement, and is intended for a speed of 20 knots, with 3,250 I. H. P. The engines are twin-screw triple-expansion, each set of engines and each pair of boilers being in a separate compartment.

Normannia.—This vessel, which will soon be put on the Atlantic route, is a twin-screw steamer built by the Fairfield Co. for the Hamburg-American Packet Co. She has two pole masts, is 500 feet long, 57½ beam, 38 deep (moulded), 34½ depth of hold, and displaces 11,500 tons on a draught of 24 feet. There is a central longitudinal bulkhead between the engine rooms, and

eleven transverse bulkheads, dividing the ship into thirteen watertight compartments. There are three boiler compartments, each containing three eight-furnace boilers, 16 feet diameter and 18 feet long. The engines are triple-expansion, with cylinders 40, 67 and 106 inches diameter by 66 inches stroke; they were designed for 14,000 I. H. P., with natural draft, with which the vessel is expected to make 19 knots. There are, however, two 6-foot fans in each fire room.

She had a trial on the 3d of May, during which the speed is said to have been 21 knots per hour.

City of Paris.—The recent remarkable accident to the machinery of this vessel has attracted the most intense interest not only of engineers, but of the world. The first news naturally came through the daily press, and amounted to this: that on March 25, while the vessel was about 216 miles from the coast of Ireland and everything was working well and promising a fast trip, a grinding noise was suddenly heard in the starboard engine room, quickly followed by the stoppage of that engine. The port engine continued working, but it, too, soon stopped. Both engine rooms filled with water, showing that the longitudinal bulkhead between them was ruptured, but the athwartship bulkheads perfectly protected the fire rooms, which remained in the usual condition. No information of the details of the accident were given out, and it was generally supposed that a connecting rod had broken, and, sweeping around like a huge flail, had broken through both inner and outer skins and the longitudinal bulkhead between the engine rooms. The ship was perfectly helpless, and was finally towed into Queenstown. Here divers repaired the longitudinal bulkhead, and the vessel steamed to Liverpool under her port engine, where she was turned over to Messrs. Laird, of Birkenhead, for complete repair.

With a consideration for the interest of engineers and the public in this accident almost unprecedented, the owners of the vessel gave every facility to representatives of the engineering journals for securing complete data of the condition of affairs. The two great London weekly journals, *The Engineer* and *Engineering*, have given in their issues of April 18 and 25 detailed

accounts with illustrations, after photographs, of the condition of the machinery after the vessel was docked and the water removed. We cannot do better than copy portions of these accounts verbatim, and the following extracts are from *The Engineer:*

"At half-past five on the evening of Tuesday, the 25th of March, the *City of Paris* was about 216 miles from the coast of Ireland, running at full speed. There were in each engine room at the time three men, one on each platform. The man on the top platform felt the tail-rod of the low pressure engine and went forward. He had not gone five steps when the whole low pressure engine fell to pieces. In a few seconds this great engine, standing about 45 feet high, was a heap of scrap. We examined the engine room carefully before anything had been removed, and the result of that examination was to show that everything that could be broken had been broken, and what could not be broken was bent, twisted or distorted. The intermediate and high pressure engines are quite intact to all appearance. Portions of the rubbing face on the intermediate cylinder have been broken away, but so far as we could see there was nothing to prevent the engines working. The low-pressure cylinder was cast in one with its four valve boxes, the weight of the rough casting being about 45 tons. This cylinder is in fragments. Going out to the end of what remains of the upper platform, we had before us a great chasm, and at the bottom of the chasm an enormous heap of scrap iron. Nothing so complete in the way of a breakdown has ever before been seen. The explosion of a great shell might work such havoc in an iron clad. It is difficult, in the face of such total destruction, to form any theory as to what gave way first.

"Descending to the crank platform, and climbing over and crawling under heaps of fragments, we find some curious things. The top cylinder cover seems to be at the bottom of everything. The A-frames have apparently disappeared bodily. The connecting rod is still coupled to the crank pin, the big end intact, but the rod, about 14 inches diameter in the middle, is bent. The piston rod and crosshead are still coupled to the connecting rod, and lie folded back. The tail-rod is bent like a bit of wire, nearly in a semi-circle. One side of the condenser has been torn out. The tubes are all displaced and a good many of them flattened until they are no thicker than the blade of a breakfast knife. The air-pump levers are literally rolled up like bits of ribbon.

On the side of a part of the cylinder is a great crack, but the metal holds together still in a way to demonstrate toughnesss of no ordinary degree. We are puzzled to imagine how it has been possible that material so excellent should have been so completely destroyed. There is not a broken bar or bolt that does not show that it has only given way as a result of the utmost violence. We begin to ask ourselves whether, if a charge of dynamite had been put in the cylinder and exploded it would have wrought more havoc.

"But the ruin is not confined to the engine room; the great screw shaft, 21 inches diameter and over 100 feet long, has been ripped up out of its bearings from one end of the screw tunnel to the other, and then dropped back again. All the cap bolts are smashed and a great rent is forn in the bulkhead where the shaft passed through it. The half-inch steel plate has been bent and buckled like a bit of paper. All the horseshoes were torn out of the thrust block and scattered over the engine room.

"The smashing of the condenser was followed by an enormous rush of water into the engine room.

"As to the precise nature of the injuries inflicted on the ship by the ruin of the engine, the wildest statements have been made by persons who have written in absolute ignorance of what took place. One sober journal told its readers that a large portion of the cylinder had gone clean through the bottom of the ship. Now, in point of fact, nothing went through the ship. What happened engineers will have already pretty well gathered from what we have said. The condenser lies low in the ship, considerably under the water line. It is supplied by Gwynne's centrifugal pumps, drawing water through a copper pipe nearly two feet in diameter. The pumps and the condenser were wrecked, and the water, of course, rushed in like a cataract through the broken pipes. The man on the lower platform at the time of the accident was standing close to the after end of the condenser, and had a miraculous escape, one of the largest portions of the cylinder very nearly catching him in its fall. He fled for his life past the condenser. If he had remained, he would have been drowned. He had no time to close the Kingston valve, even if he could have got at it under the *debris*. This, then, accounts for the flooding of the starboard engine room. The tail-rod of the low-pressure engine was driven through the bulkhead between the engine rooms tolerably high up, making a circular hole nearly a foot in diameter. A heavy longitudinal shelf-piece lying some eight or ten feet above the crank platform strengthens the bulkhead. Just under this a large, ragged hole was torn, by what

it is impossible to say. An attempt was made to stop both these holes with mattresses, held up with shores, but these did no good. The engineers did all they could, but they were ultimately driven out of the port engine room by the rising water. The screw shaft was, as has been said, ripped up out of its bearings and then dropped again; but in lifting up it tore the after bulkhead and left a large aperture, through which the water rushed, filling the dynamo room and shaft alley. Not a drop of water got into the boiler room.

"The rush of steam into the engine room was, for a moment, tremendous, but the instant the engines stopped no more steam could escape, save that which might leak past the valves and pistons of the high-pressure and intermediate cylinders. The engineers rushed into the engine room and screwed down the stop valve with commendable courage and promptitude.

"After the ship was docked and as the water left her, it became apparent that the outer length of shafting must be broken, as the coupling had broken through part of the casing and the propeller had slipped aft 15 inches. While the cover was being taken off to inspect the shaft, the forward end of the shafting fell down to the bottom of the dock. The strain on the bracket, which had become worn down, was too great for it to sustain, and it broke, letting the other end of the shafting, with boss and blades, down to the bottom of the dock. The weight of the whole of this would be upwards of forty tons. By the fall in the dock one of the manganese blades was doubled up in an extraordinary fashion, without showing the least crack.

"Nothing so bad ever occurred in an engine room before. It is impossible, indeed, to imagine that anything worse can take place; yet the skins of the ship are uninjured. Not a single rivet in the hull has been started; not a life has been lost, and no one was hurt, save one engineer slightly scalded.

"As to the cause of the accident, experts in Liverpool are satisfied that the thing which first gave way was not in the engine room, but that the sequence of events was as follows: The brass liner on the tail (propeller) shaft burst; then the lignumvitae strips were torn out, bringing metal to metal; then the tail shaft ground away the liner in the stern bracket; then the steel shaft ground away itself and the bracket, and the shaft dropped; then the continual bending action which took place resulted in the shaft breaking just where it came out of the stern tube; then the engines raced, resulting in the accident which we have already so fully described."

In an editorial of April 25th, *The Engineer* advances another hypothesis to account for the accident. It is pointed out that the assumption that the shaft broke first, and that the engines then raced and so caused the accident, is not borne out by facts. Breakages of propeller shafts are common, but never before was there any such result as in this case. Confirmatory evidence exists in our own service. It will be remembered that on her first trial trip the *Dolphin's* shaft broke, and that the engines raced badly till steam could be shut off, but no damage whatever occurred to anything but the shaft. The suggestions of foaming due to the racing, and of greatly increased back pressure in the low pressure cylinder due to an overloaded condenser, are also discussed and rejected. The editorial goes on to say:

"We may now turn to the positive evidence available to prove that a totally different cause must be sought for the catastrophe. This positive evidence is supplied by the screw alley. We find that the screw shaft was lifted up out of its bearings from end to end, and the lifting up has been of such a character as to prove that the lifting effort occurred in the engine room. The screw shaft is secured to the end of the crank shaft in the usual way by a cheese coupling and bolts. We must ask our readers to note carefully what follows. The crank and screw shafts were virtually one from the forward end of the engine room to the stern tube. The cap bolts of the after bearings on the crank shaft, although five inches in diameter, were broken short off, but the cap bolts of the other bearings are intact. Proceeding aft, we find that the cap was torn off the thrust block and the horseshoes scattered about the engine room. From this, back to the stern tube, all the keeps were torn off save the last. It is perfectly clear that the screw shaft was lifted up in the engine room, and that for the moment it was several inches higher in the engine room than at the stern tube. How, it will be asked, was it possible that the shaft could be so lifted, while the crank shaft to which it was secured remained tied down? The answer is curious, and yet simple. The crank shaft is built up. Let us suppose that while the crank shaft was descending, which would be the case when it was pointing toward the ship's side, the screws revolving outboard at the top, some obstruction got under it and stopped it suddenly. The momentum of the heavy screw would

tend to cause the shaft to revolve around the crank pin. This it could not do without bursting up the keeps, and even then either the web must slip round on the crank pin, or it must twist the pin. Now, in point of fact, the pin has not been twisted, but the crank web has slipped round on the pin, and the screw shaft is no longer in line with the crank shaft center. It is abundantly clear, from the facts we have stated, that something occurred to stop the revolution of the shaft; but further evidence is supplied by a great score in the crank web, due, apparently, to collision with some obstacle.

"We are now in a position to advance an explanation which, though not complete, goes some little way towards completeness. The screw shaft was no doubt injured by bending, as we explained last week. The breakdown was brought about by some obstruction which prevented the rotation of the crank shaft. The screw then ripped up the shaft out of its bearings, and the weakened tail end, being unable to bear the strain, broke. The sudden jerk on the guides was, of course, tremendous. The connecting rod was bent, and the steel frames were, by the side effort, snapped off short at the bed plate. In this there is nothing remarkable; the breaking of steel frames is not an uncommon occurrence. The question remaining for solution is, what caused the obstruction to the rotation of the crank? This is a point whose clearing up is in the future, but we give the following for what it is worth. The low-pressure piston was a steel casting with a thin coned body and a heavy rim to take the packing. In such a casting it is almost impossible to eliminate severe initial stresses, set up during cooling. The cracking of large pistons is an exceedingly common occurrence, and we could cite more than one recent case where a thin conical piston has parted from the rod. If the piston broke and a large portion of it fell to the bottom of the cylinder, the remaining portion coming down on this would cause just such a jar as was needed for the lifting of the screw shaft in the way we have described. The bursting of the cylinder would take place at the same instant. It is quite on the cards, however, that the piston broke near the top of the stroke, and that the first effort of the engine took the form of ripping the top cylinder cover off, which fell down in fragments, the cylinder bursting at the same time and fracturing the steel legs. The ruins of the engine tumbling into the crank pit did the rest. It is quite possible, however, that the steel legs gave way before anything else; the other two engines would, nevertheless, keep the crank shaft revolving. Whatever the obstacle

was that checked the crank, it is evident that the crank cleared it after striking, for the crank was found on the top center.

"No doubt a goodly number of theories will be framed to account for this most astonishing breakdown, but none can be considered even moderately satisfactory that does not explain how the screw shaft was lifted."

Sunderland (Torpedo Boat).—Special interest attaches to this little vessel, referred to on page 183, vol. I, on account of the use of petroleum as fuel. The account of the vessel and machinery, which is abstracted from *Engineering* for January 10, 1890, will, it is believed, prove interesting and valuable. The dimensions of the hull are as follows: length between perpendiculars, 137 feet; beam, 13 feet 9 inches; draught, forward, 3 feet 10 inches, aft, 4 feet 2 inches, mean, 4 feet; displacement, 86.2 tons; immersed midship section, 40 square feet. The plating is of galvanized steel, and there is a double bottom forming the storage tanks for the petroleum, though they can also be used for water ballast; their total capacity is 13.8 tons.

There is a single screw driven by a triple-expansion engine with cylinders 15, 22 and 33½ inches diameter by 18 inches stroke. The engines present no specially novel features, but are good examples of torpedo boat practice, the large bearing surfaces and well-balanced parts together with the lightness of the reciprocating parts, enabling them to run at a high speed. The arrangements for lubrication are very complete, every important journal having a separate oil pipe leading to the front of the cylinders where it terminates in a small sight cup and valve. These cups are fed from a horizontal pipe connected to a tank just under the deck above. Double-bar links and piston valves are used. The main pistons are of the usual dished form, and are fitted with Ramsbottom rings. Parson's white metal is used for the bearing surfaces in main and crank-pin journals, the former having an aggregate length of 56½ inches. The crank shaft is a single forging, 5¼ inches in diameter, with a 2-inch hole through the pins and a 1½-inch hole through the shaft. The eccentrics and straps are of cast steel, the latter being lined with Parson's white metal.

The air pump is single-acting, 16½ inches diameter by 6 inches stroke, driven by levers and a connecting rod from a crank forged on the end of the main crank shaft. The levers also drive a bilge pump 2½ inches diameter by 6 inches stroke at one end of the air pump cross-head, and from the other a similar pump for circulating water through the main cross-head guides and other places. The condenser, which is placed at the back of the engines is of sheet copper and flanged in sections, these being bolted together with stiffening rings to withstand the external pressure. There are 862 tubes, of brass, ⅝-inch in external diameter, the total cooling surface being 1,745 square feet. The circulating water is obtained by natural means, somewhat after the manner of the old Lighthall refrigerator, there being adjustable scoops for directing the water through the condenser while the vessel is in motion. A 4-inch circulating pump is used at other times.

The thrust block has twelve rings, all faced with Parson's white metal, and each lubricated by a separate sight cup and valve. The propeller is of cast steel, three-bladed, 6 feet diameter and 8 feet 3 inches mean pitch. The blades are planed on both faces to an absolutely true and smooth surface and knife edge, and each blade is the exact counterpart of its neighbors in form and weight.

The boiler is of the ordinary locomotive type with wet bottom. The furnace front is arranged to receive the oil burners, which are 31 in number. There are 419 tubes, 2 inches in external diameter and 9 feet long between tube plates. The total heating surface is 2,173.8 square feet, and the steam capacity is 305 cubic feet. The liquid fuel used is pumped by a small Worthington pump from the double bottom, and discharged into a small cylindrical tank near the side, where it is subjected to an air pressure of 35 pounds per square inch, and whence it flows direct to the burners. The stokehold also contains an air compressor which discharges into cylindrical air tanks near the vessel's side, forming a group of four, inclusive of the air tank already referred to. The working pressure of air in these tanks is 40 pounds per

square inch, and it is conveyed here for the purpose of disintegrating the oil as it leaves the burners.

Each jet of oil results in a clear, bright flame, about 6 feet 6 inches long and 9 inches in diameter if burning alone. When the jets are combined in the fire box there results a bright mass of fire about 2 feet from the furnace mouth to the tube plate. The flame entirely fills this portion of the furnace, and gives forth neither smoke, smell nor sparks, so that neither soot nor dust is deposited in the tubes, and no sweeping is required. Each burner can be made to consume from 25 to 75 pounds of oil per hour, and any one or all may be shut off by a simple arrangement under the complete control of one man. Forced draft is obtained by a closed fire room, the air pressure for full power being 6½ inches of water.

Special precautions are taken to avoid the bad effects of high temperature and rapid changes of temperature, and it is stated that these are so efficient that, though the boiler has been repeatedly forced very hard, there has not been a sign of leakage about the tubes or seams.

The only economic data with reference to the oil fuel given is that for one run at 20 knots, 1,001 I. H. P. was obtained with an expenditure of 1,001 pounds of heavy oil per hour. It is stated, however, that improvements in the oil-burning apparatus will reduce this amount.

The special advantages claimed for liquid fuel are:

Greater efficiency than coal, weight for weight.

Manner of stowing (in the double bottom) gives increased stability and increase of available space.

Special adaptation to manœuvring.—In manœuvring under steam, it may be often desirable to stop suddenly while at full speed, and not use the engine for some time. With coal fires, this is hard to do, necessitating the use of the "bleeder," and, moreover, the fires soon become dirty. With the liquid fuel, as many burners as necessary may be shut off when the engine is stopped, only enough being kept in operation to prevent the steam pressure from falling. When full power is again needed, it can be had at once, with everything clean and in good shape.

PROGRESSIVE TRIALS OF TORPEDO BOAT *SUNDERLAND*.

Number of run.	North or South.	Time.	Speed in knots.	Mean speed.	Indicated horse power.	Mean I. H. P.	Revolutions per minute.	Mean revolutions.	Slip per cent.	Displacement.	$D^{\frac{2}{3}} \times S^3$ I. H. P.	Indicated thrust in pounds.	Boiler pressure.	Pressure in steam pipe.	Pressure in first receiver above atmosphere.	Pressure in second receiver above atmosphere.	Vacuum.	Temperature of feed water.	Number of burners in use.	Compressed air pressure.	Oil pressure.	Air pressure in inches of water.
		m. s.											*lbs.*	*lbs.*	*lbs.*	*lbs.*	*ins.*			*lbs.*	*lbs.*	
1	N.	4 30	13.33	14.04	244	232.5	293	295	15.87	86	232.4	4,536	148	140	10½	-7	25	120	4	33	28	1¾
2	S.	4 4	14.75		231		307						160	142	13	-6½	25½	125	5	33	30	1¾
3	N.	3 57	15.75	16.03	486	472.5	850	847.5	20.5	86	169.7	7,636	157	150	28	-1½	24½	130	6	35	30	1¾
4	S.	3 53½	16.88		459		845						153	150	28	-1½	24½	135	6	35	30	1¾
5	N.	3 51½	16.33	17.37	658	648.5	873	874.5	22.07	85½	156.6	9,450	157	150	39	-1½	24½	135	9	35	30	3¼
6	S.	3 49½	18.41		645		876						158	135	41	0	23¾	135	10	35	30	3¼
7	N.	3 48	18.37	19.53	971	969	876	876	24.09	85	148.4	12,266	158	135	60	8	24	100	15	35	30	4¾
8	S.	3 46	20.69		967		876						158	135	60	8	24	100	15	35	30	4¾
9	S.	3 54	20.57	19.56	1,081	973.5	848	846	23.95	84½	148.1	12,323	158	140	65	10	24	100	17	35	30	5¼
10	N.	3 55	18.56		946		844						148	140	63	9½	23¾	100	17	35	30	5¼
11	S.	3 40	22.56	21.03	1,346	1,203.5	854	852	26.6	84	148.2	13,676	160	156	70	15	24	125	21	35	30	6¼
12	N.	3 4	19.56		1,187		850						158	155	70	15	24	125	21	35	30	6¼

Smaller personnel than with coal.—This is so evident as hardly to need mention.

Cleanliness.—There is no dirt attendant upon the reception or use of the fuel, no smoke from the chimneys, and no ashes or refuse.

The table on the preceding page gives the data of the progressive trials of this little vessel, and deserves very careful study.

MEMORANDUM IN REGARD TO THE ARTICLE ON THE "MARSHALL VALVE GEAR," BY PASSED ASSISTANT ENGINEER I. N. HOLLIS, IN NO. 1 OF VOL. II, PP. 1–25:

Since the publication of this article the Council has received a letter from Mr. Gustav A. C. Bremme, the inventor of the valve gear which is commonly designated as Marshall's, requesting that publicity be given to the fact that he is the real inventor.

The Council willingly inserts this note. The fact of Mr. Bremme's prior invention and of Mr. Marshall's acknowledgment of the same have been so often stated in engineering literature that it is supposed that every engineer who is at all *au courant* with the information of the day is aware of the true state of the case. In using the title he did, Mr. Hollis simply gave the name by which the gear is always designated in this country, and without any idea of depriving Mr. Bremme of the credit due him.

ANNUAL MEETING.

At the annual meeting of the Society, held at Washington April 23d, the report of the Secretary and Treasurer, Passed Assistant Engineer R. S. Griffin, U. S. Navy, was received and referred to the Council, by whom it has since been approved, It shows the Society to be in good financial condition.

The election of officers for the ensuing year followed the report, and the officers of last year were re-elected, with the exception of Mr. Griffin, who declined a renomination.

A vote of thanks was passed for his efficient management of the affairs of the Society and editorial work on the JOURNAL.

The officers for the current year are:

President: Chief Engineer N. P. TOWNE, U. S. Navy.

Secretary and Treasurer: Assistant Engineer W. M. MCFARLAND, U. S. Navy.

Council: Chief Engineer N. P. TOWNE, U. S. Navy; Assistant Engineer W. M. MCFARLAND, U. S. Navy; Passed Assistant Engineer G. W. BAIRD, U. S. Navy; Passed Assistant Engineer J. H. PERRY, U. S. Navy; Assistant Engineer EMIL THEISS, U. S. Navy.

The following is the report of the Secretary and Treasurer:

WASHINGTON, D. C., *April 23, 1890.*

GENTLEMEN:

In conformity with Section 13 of the By-Laws of the American Society of Naval Engineers, I have the honor to submit the following statement of the affairs of the Society for the first year of its organization:

RECEIPTS FIRST YEAR, 1889.

From subscriptions,	$1,135.00	
" sale of JOURNAL,	10.00	
" miscellaneous sources,	3.90	
		$1,148.90

EXPENDITURES.

For publication of JOURNAL, .	$657.75	
" lithographing, ...	178.75	
" incidental expenses, postage, stationery, etc., ...	47.74	
		$884.24
Balance on hand Dec. 7, 1889, . .		$264.66

Respectfully submitted,

R. S. GRIFFIN,
Passed Assistant Engineer, U. S. Navy,
Secretary and Treasurer.

To the Council of
THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

It is gratifying to report that the membership of the Society is steadily increasing, and that among the associates are some of the most prominent engineers and manufacturers of the country.

The JOURNAL is exchanged for the proceedings of several eminent engineering societies, and has received flattering commendation from many readers whose opinions carry great weight.

In an early number will be given a complete list of the members and associates and of the societies exchanging publications.